Radiological Health Data

VOLUME II, NUMBER 10

OCTOBER 1961

Quarterly Report

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data is published by the Public Health Service on a monthly basis. Data are provided to the Division of Radiological Health by other Federal agencies, State health departments, and foreign governments. Except where material is directly quoted or otherwise credited, summaries and abstracts are prepared by the staff of the Data Collation and Analysis Unit, Division of Radiological Health. The reports are reviewed by a Board of Editorial Advisors with representatives from the following Federal agencies:

Department of Health, Education, and Welfare
Atomic Energy Commission
Department of Defense
Department of Commerce
Department of Agriculture

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RADIOLOGICAL HEALTH DATA

QUARTERLY REPORT OCTOBER 1961

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Radiation Surveillance Network

Division of Radiological Health, Public Health Service

The Public Health Service Radiation Surveillance Network was established in 1956 in cooperation with the Atomic Energy Commission to provide a means of promptly determining increases in levels of environmental radioactivity due to fallout from nuclear weapons tests. During the period reported, it consists of 45 stations at urban locations (see figure 1) operated by State and local health department personnel with 2 of the stations operated by Public Health Service personnel.

Measurements of gross beta radioactivity in air are taken as they provide one of the earliest and most sensitive indications of increases of activity in the environment and thus act as an "alert" system. A direct evaluation of biological hazards is not possible from these data alone. Field measurements enable the operator to estimate the amount of beta activity of particulates in air at the station five hours after collection by comparison with a known source using a portable survey meter. The filters are then forwarded to the central laboratory of the Radiation Surveillance Network in Washington, D.C., for a more refined measurement using a thin window proportional counter. The station located at Atlanta, Georgia, conducts its own laboratory analyses.

Air samplers were in operation at the 45 stations on an average of 70 percent of the week. Air is drawn through a cellulose carbon-loaded dust filter using a high volume air sampler. The radioactive material in fallout adhering to small particles is retained on the filter. Some gaseous fission products are adsorbed by the carbon. The contribution by gaseous fission products has represented only a small part of the total beta activity in these samples.

Values for May 1961 as presented in table 1 are generally below limits of detection by present instrumentation.

Due to the resumption of nuclear weapons testing, a renewed interest in the results of the Radiation Surveillance Network has been evidenced. Field measurements of gross beta determinations from stations showing increased readings have been released by the Public Health Service and published almost daily by newspapers. Table 2 presents confirmed daily laboratory results for the first 18 days of September for stations selected to provide geographical coverage. The results for June, July, and August will be published as soon as possible.

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

TABLE 1.—RADIOACTIVITY OF PARTICULATES IN AIR, MAY 1961 GROSS BETA DETERMINATIONS

Station location	Number samples	Maximum ($\mu\mu c/m^3$)	Minimum ($\mu\mu c/m^3$)	Average[1] ($\mu\mu c/m^3$)	Station location	Number samples	Maximum ($\mu\mu c/m^3$)	Minimum ($\mu\mu c/m^3$)	Average[1] ($\mu\mu c/m^3$)
Anchorage, Alaska	22	0.36	<0.10	<0.15	Minneapolis, Minn	9	0.23	<0.10	<0.13
Fairbanks, Alaska	20	0.27	<0.10	<0.15	Pascagoula, Miss	19	0.38	<0.10	<0.15
Juneau, Alaska	14	0.35	<0.10	<0.16	Jefferson City, Mo	22	0.30	<0.10	<0.14
Phoenix, Ariz	2	0.24	0.23	0.23	Helena, Mont	22	0.30	<0.10	<0.15
Little Rock, Ark	21	0.22	<0.10	<0.14	Trenton, N. J	16	0.26	<0.10	<0.16
Berkeley, Calif	18	<0.10	<0.10	<0.10	Santa Fe, N. Mex	17	0.38	<0.10	<0.23
Los Angeles, Calif	20	0.17	<0.10	<0.11	Albany, N. Y	17	0.22	<0.10	<0.14
Denver, Colo	15	0.23	<0.10	<0.14	Gastonia, N. C	23	0.30	<0.10	<0.17
Hartford, Conn	31	0.34	<0.10	<0.14	Oklahoma City, Okla	20	0.26	<0.10	<0.17
District of Columbia	25	0.29	<0.10	<0.16	Ponca City, Okla	29	0.18	<0.10	<0.11
Jacksonville, Fla	23	0.23	<0.10	<0.16	Portland, Oreg	23	0.21	<0.10	<0.12
Atlanta, Ga	14	0.21	<0.10	<0.12	Harrisburgh, Pa	18	0.24	<0.10	<0.14
Honolulu, Hawaii	22	0.14	<0.10	<0.10	Providence, R. I	20	0.24	<0.10	<0.15
Boise, Idaho	8	0.27	<0.10	<0.17	Columbia, S. C	7	0.15	<0.10	<0.13
Springfield, Ill	9	0.26	<0.10	<0.14	Pierre, S. Dak	8	0.30	<0.10	<0.18
Indianapolis, Ind	31	0.26	<0.10	<0.15	Austin, Tex	23	0.25	<0.10	<0.14
Iowa City, Iowa	22	0.25	<0.10	<0.15	El Paso, Tex	20	0.57	0.16	0.31
Topeka, Kans	23	0.22	<0.10	<0.14	Salt Lake City, Utah	30	0.30	<0.10	<0.15
New Orleans, La	1	0.14	0.14	0.14	Richmond, Va	22	0.22	<0.10	<0.13
Baltimore, Md	21	0.31	<0.10	<0.15	Seattle, Wash	22	0.12	<0.10	<0.10
Lawrence, Mass	19	0.20	<0.10	<0.12	Madison, Wis	26	0.28	<0.10	<0.16
Lansing, Mich	31	0.31	<0.10	<0.17	Cheyenne, Wyo	8	0.16	<0.10	<0.13

[1] Weighted average obtained by summing the products of individual sampling times and the corresponding activities, and dividing by the summation of the individual sampling times.

TABLE 2.—RADIOACTIVITY OF PARTICLES IN AIR—DAILY SAMPLES AT SELECTED RADIATION SURVEILLANCE NETWORK STATIONS, SEPTEMBER 1–18, 1961

[Concentrations in $\mu\mu c/m^3$]

Station location	Sept. 1	Sept. 2	Sept. 3	Sept. 4	Sept. 5	Sept. 6	Sept. 7	Sept. 8	Sept. 9	Sept. 10	Sept. 11	Sept. 12	Sept. 13	Sept. 14	Sept. 15	Sept. 16	Sept. 17	Sept. 18
Anchorage, Alaska	<0.10	[a] NS	NS	NS	7.73 [c](5)	9.5 (4)	0.20	<0.10	<0.10	0.22	0.11	0.18	1.05 (5)	2.87 (5)	2.19 (15)	0.3	1.27 (7)	2.05 (10)
Los Angeles, Calif	<0.10	<0.10	[b]—	<0.10	<0.10	<0.10	<0.10	<0.10	1.72 (6)	1.72 (8)	0.14	0.96 (9)	1.18 (14)	1.58	0.82 (15)	0.81	0.56 (8)	0.70 (10)
Washington, D. C	<0.10	<0.10	<0.10	<0.10	<0.10	0.22	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.46 (11)	0.85 (12)	1.27 (6)	63.73 (6)	23.49 (8)
Jacksonville, Fla	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	—	1.30 (11)	4.02 (13)	401.16 (8)
Springfield, Ill	<0.10	—	—	—	—	—	<0.10	—	<0.10	<0.10	<0.10	<0.10	<0.10	0.13	0.59 (17)	1.40 (15)	2.51 (10)	NS
Topeka, Kans	<0.10	NS	NS	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	<0.10	—	1.10 (13)	1.88 (15)	2.16 (16)	2.36 (20)
New Orleans, La	NS	<0.10	NS	<0.10	<0.10	—	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.57 (9)	0.98 (15)	1.31 (15)	1.69 (14)	297.07 (8)
Lansing, Mich	—	—	—	—	—	—	—	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	—	0.67 (13)	1.99	38.34 (7)	35.83 (10)
Minneapolis, Minn	NS	NS	NS	<0.10	NS	NS	<0.10	<0.10	<0.10	<0.10	<0.10	0.15	—	—	—	1.23 (20)	2.26 (16)	1.99
Albany, N. Y	<0.10	—	—	—	—	—	—	—	<0.10	<0.10	<0.10	<0.10	0.74	0.15	0.62 (12)	NS	58.21 (7)	14.12 (8)
Gastonia, N. C	<0.10	NS	NS	NS	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	—	1.09 (10)	NS	106.50 (6)	80.31 (9)
Austin, Tex	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	NS	0.75 (14)	2.23 (12)	2.16 (11)	4.78 (15)
Salt Lake City, Utah	<0.10	<0.10	<0.10	<0.10	<0.10	—	<0.10	<0.10	0.89 (6)	<0.10	4.2 (18)	6.20 (11)	15.0 (12)	14.37 (13)	5.10 (15)	0.73 (15)	0.59 (9)	0.26
Seattle, Wash	<0.10	—	—	—	NS	<0.10	<0.10	<0.10	0.31 (11)	<0.10	<0.10	<0.10	0.92 (11)	3.48 (6)	0.92 (10)	0.48	0.32	0.41 (6)

[a] NS, No sample.
[b] —Not known.
[c] Figures in parentheses denote age of fission products in days.

Surface Air Radon, Thoron, and Fission Product Gross Beta Concentrations at Cincinnati, Ohio

Robert A. Taft Sanitary Engineering Center, Public Health Service

Natural background radioactivity in our atmosphere is an important public health consideration because the exposure levels from natural radiation can be used as a base for comparative evaluations of exposures from artificially produced radionuclides. Natural radioactivity in surface air is attributed to a number of unstable nuclides other than those produced by man. The earth's crust contains trace amounts of uranium and thorium that occur naturally and which decay through a series of their daughter products. These decay products of uranium and thorium are introduced into surface air through their rare gas daughters, radon (radon-222) and thoron (radon-220), which in turn continue to decay through the uranium and thorium series, respectively. The radon and thoron content of air depends on the escape of these rare radioactive gases from the earth. Concentrations depend on prevailing atmospheric conditions such as ambient temperature, humidity, and pressure, and on soil conditions such as moisture, porosity and temperature.

Most of the natural radioactivity in surface air is due to radon (Rn^{222}) and its daughters. Thoron (Rn^{220}) and its daughters contribute much less because of thoron's short half-life and hence, a lower diffusion rate from the soil.

The Radiological Health Research Activities, Research Branch, Division of Radiological Health, Public Health Service, performs a continuous daily sampling program for radon (Rn^{222}), thoron (Rn^{220}), and gross beta fission product concentrations in surface air. The gross beta activity of atmospheric particulates, when measured several days after sample collection, is principally due to artificially produced radionuclides.

Air is filtered through a membrane filter, and the daughter products of radon and thoron, which are particulates, are deposited on the filter. Measurements of the alpha activity on the filter are related to the concentrations of radon or thoron in surface air. Most of the activity of radon daughters, that have a composite half-life of approximately 0.5 hour, would decay to 0.5 percent of the original value in less than four hours. The activity of thoron daughters that have a composite half-life of 10.6 hours, would decay to 0.5 percent of its original value in about four days. For this reason the gross beta determinations are made at least four days after the end of each sampling period.

Radon-222 concentrations are determined from alpha measurements made immediately after the sampling period (24 to 72 hours) has ceased. Reported radon-222 (a.m.) concentrations have been corrected for any radon-220 daughter interferences. Radon-222 (p.m.) concentrations are derived from alpha measurements made in the afternoon (3 p.m.) approximately 7 hours after the new sampling period has begun. These values are from the same filters that are counted at 8 a.m. the following day. Reported radon-222 (p.m.) concentrations are uncorrected for any radon-220 daughter interferences. Radon-220 concentrations are determined from alpha measurements made on the same sample used to evaluate the corrected radon-222 (a.m.) concentrations, but are counted 7 hours after the sampling period has ceased. Reported values are corrected to the time of removal of the filter holder.

There has been a recent change in the reporting period because the data are now computed by an electronic data processing system which is programed for thirteen four-week periods per calendar year. The data for the period May 22–June 16, 1961 appear in table 1.

REFERENCE

Setter, L. R. and Coats, G. I., "The Determination of Airborne Radioactivity," American Industrial Hygiene Association Journal, Vol. *22*, Number 1, February 1961.

TABLE 1.—SURFACE AIR RADON, THORON, AND FISSION PRODUCT GROSS BETA CONCENTRATIONS, MAY 22–JUNE 16, 1961

End of sampling period	Continuous sample collection			Rn^{222} [a] 8 a.m. ($\mu\mu c/m^3$)	Rn^{222} [b] 3 p.m. ($\mu\mu c/m^3$)	Rn^{220} [c] ($\mu\mu c/m^3$)	Beta [d] activity ($\mu\mu c/m^3$)
	Sample change time	Sample period (hours)	Volume (m^3)				
May 22	0809	72.0	85.1	160	40	3.1	0.15
23	0805	24.3	29.5	390	70	3.6	0.13
24	0816	24.1	29.5	570	70	4.8	0.11
25	0809	23.8	29.0	390	110	5.1	0.16
28	0806	23.9	28.8	70	60	1.8	0.12
29	0806	71.9	87.3	370	160	5.1	0.10
31	0807	48.0	56.6	820	110	2.6	0.21
June 1	0830	24.4	29.0	260	170	4.4	0.21
2	0802	23.5	28.5	200	200	3.3	0.20
5	0804	72.0	86.4	670	240	7.4	0.11
6	0817	24.1	29.3	230	100	2.5	0.06
7	0804	23.7	28.4	360	120	4.1	0.23
8	0805	24.0	28.4	150	120	2.2	0.08
9	0804	23.9	28.3	140	110	1.3	0.11
12	0807	72.0	85.0	700	170	6.3	0.09
13	0800	23.9	28.1	330	160	3.0	0.23
14	0804	24.0	28.3	180	130	1.3	0.06
15	0800	23.9	28.2	70	50	0.8	0.00
16	0800	23.9	28.6	160	40	1.1	0.04
Average				327	120	3.4	0.13

[a] Twice the standard deviation (2σ) falls between ± 14 and ± 51 $\mu\mu c/m^3$.
[b] Twice the standard deviation (2σ) falls between ± 10 and ± 27 $\mu\mu c/m^3$.
[c] Twice the standard deviation (2σ) falls between ± 0.3 and ± 0.9 $\mu\mu c/m^3$.
[d] Twice the standard deviation (2σ) falls between ± 0.01 and ± 0.07 $\mu\mu c/m^3$.

SAMPLING PROGRAMS FOR RADIOACTIVITY IN AIR

The following articles are the third and fourth in a series of papers intended to present summaries or selected discussions concerning atmospheric levels of radioactivity. The first of the two presented here discusses and statistically compares the surface air fission product gross beta concentrations analytically defined by two Public Health Service atmospheric sampling programs—the National Air Sampling Network (NASN), Division of Air Pollution, and the Radiation Surveillance Network (RSN), Division of Radiological Health. The data, analysis and discussion were compiled and prepared by Dr. Bernard Shleien and Mr. Thomas A. Entzminger of the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

This statistical comparison, performed on data from a selected number of sampling points over a specified period of time, shows that different sampling techniques and analytical procedures performed by different laboratories will influence the fission product gross beta concentrations reported by the respective sampling programs. The specific location of the air samplers are subject to considerations such as local climatological and topographical factors. No attempt has been made to determine the relative effect which each of these considerations contributes to the variations observed.

The authors wish to express their appreciation to the Divisions of Air Pollution and Radiological Health, Public Health Service, for their cooperation, and for supplying the basic data necessary for this analysis.

The second article, by Major Albert K. Stebbins, III, USAF, presents a discussion and partial summary of the most extensive stratospheric air sampling program ever performed. Known as the High Altitude Sampling Program (HASP), it is operated by the Defense Atomic Support Agency (DASA), Department of Defense. In this program, U-2 aircraft collected particulate debris on filter papers at altitudes up to 70,000 feet.

Data derived from HASP provides:

(1) stratospheric inventories of strontium-90 in the Northern and Southern Hemispheres during 1958, early and late 1959, and early 1960

(2) a hypothetical model of stratospheric mixing and transfer processes, and

(3) a limited comparison of the hazard from fallout of past weapons tests.

A Comparison of Surface Air Fission Product Gross Beta Concentrations—National Air Sampling Network and Radiation Surveillance Network

Public Health Service

The Public Health Service operates two surface air fission product gross beta sampling programs—the National Air Sampling Network (NASN) and the Radiation Surveillance Network (RSN). The principal objectives of the NASN are to develop adequate sampling procedures and to determine the amounts of specific organic and inorganic pollutants, including nuclear bomb debris, in representative air samples which are collected at urban and non-urban sites on a randomized sampling schedule. The responsibility of the RSN is to provide an immediate evaluation of environmental fission product gross beta levels, on a daily basis, at selected sampling sites. These semi-quantitative field results are then confirmed by a laboratory analysis.

Comparison of Sampling Techniques and Methods

The sampling techniques and analytical procedures employed by these two programs for evaluating surface air fission product gross beta concentrations differ. Since no field determinations are made on NASN samples, only the laboratory results have been considered in this study.

The NASN samples are obtained with high-volume air samplers which employ an 8″ x 10″ glass fiber filter capable of removing almost 100 percent of all particulates with diameters equal to or greater than 0.3 microns. The average sampling rates at urban stations range from 40 to 50 cfm. The volume of air filtered in a normal 24 hour sampling period usually averages 2000–2200 cubic meters (*1*). RSN air samples are collected with similar high-volume air samplers, but they are fitted with 4″ diameter MSA BM 2133 dust filters (*2*). The volume of air drawn through a 24 hour RSN sample is approximately 40% less than that for a NASN sample. This is probably due to greater loss of head pressure through the felt fiber filters used in RSN samplers.

The NASN samples sent to the Robert A. Taft Sanitary Engineering Center are equilibrated overnight at 75° F and 50 percent relative humidity; they are weighed, and counted for their gross beta fission product content. Similar gross beta counts are made two to four days after collection, and again four to six days later. This facilitates an extrapolation to date of collection. Gross beta activities are measured by placing the entire 8 x 10-inch filter beneath a 7.5 inch diameter thin window (Mylar) proportional gas-flow counter (NMC-PCC12) that has an over-all efficiency of about 35 percent. Uranium oxide on a 2 inch diameter stainless steel planchet is used as a secondary standard (*3*). The secondary standard is covered with an aluminum foil (7 mg/cm^2) to shield out the alpha activity.

RSN samples are counted for their respective gross beta activity in a 7.5 inch diameter thin-window proportional gas-flow counter (same type as above) three to five days after collection. Determinations are made by comparison to a 0.02 μc Sr^{90}-Y^{90} source deposited on a 4 inch diameter plastic disk. A second count is made seven days after the first, and the results are extrapolated to the date of collection (*2*).

In order to relate the laboratory determinations, data were compared for cities in which samplers of both programs were at the same location. The sites were New Orleans, Wash-

TABLE 1.—AVERAGE SURFACE AIR FISSION PRODUCT GROSS BETA CONCENTRATIONS (1958) AND CORRELATION COEFFICIENTS FOR THE NASN AND RSN AIR SAMPLES COLLECTED AT THE SAME LOCATIONS

Station	Number of samples	Correlation coefficient (RSN-NASN)	NASN ($\mu\mu c/m^3$)	RSN ($\mu\mu c/m^3$)	Ratio $\left(\frac{NASN}{RSN}\right)$
Anchorage, Alaska	20	0.98	2.5	1.8	1.4
Cheyenne, Wyo	18	0.92	9.9	4.4	2.2
Little Rock, Ark	21	0.90	5.2	4.6	1.1
Minneapolis, Minn	21	0.70	3.8	2.8	1.4
New Orleans, La	22	0.69	7.0	4.7	1.5
Portland, Oreg	18	0.93	2.2	2.4	0.9
Washington, D. C	21	0.90	5.1	3.3	1.5

ington, D.C., Little Rock, Portland, Cheyenne, Anchorage, and Minneapolis. The results, for an average of twenty samples collected at the same site on the same days during the period January 1958 to December 1958, underwent a bivariate analysis for an evaluation of the correlation coefficient for each city, and the resulting linear regressions (lines of best fit) were plotted. Table 1 and figure 1 present the results of this statistical analysis. The statistical program devised for this study was such that a prediction of the RSN data can be obtained from NASN results by referring to the regression lines in figure 1.

The correlation coefficients for the data from these stations varied from 0.69 to 0.98 (average 0.86). Since it is assumed that the same air was sampled, the differences indicated must be the result of differences in sampling and laboratory procedures. Table 1 also presents the average gross beta concentrations for the samples taken at each individual station. Average surface air fission product gross beta concentrations for the NASN, on the same air samples varied from 0.9 to 2.2 times (average, 1.4) the RSN values.

A similar analysis was performed to determine the correlation coefficient for these two programs which operate sampling stations in the same urban area, but which have different sampling locations. A bivariate analysis was conducted for comparable samples from those cities. In this case, it was not assumed that the air samples obtained by these two programs were representative of the same air. Such a difference can result from differences

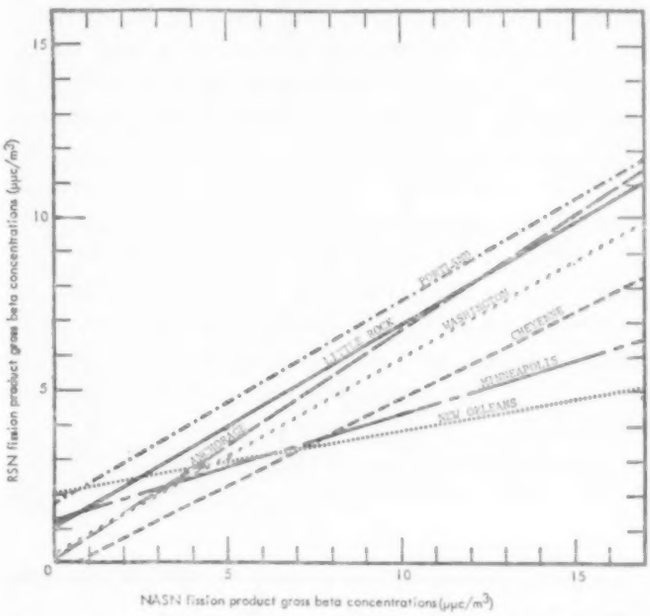

FIGURE 1.—STATISTICAL LINES OF BEST FIT (LINEAR REGRESSIONS), NASN AND RSN—SAME LOCATION

TABLE 2.—AVERAGE SURFACE AIR FISSION PRODUCT GROSS BETA CONCENTRATIONS (1958) AND CORRELATION COEFFICIENTS FOR THE NASN AND RSN AIR SAMPLES COLLECTED AT DIFFERENT LOCATIONS IN THE SAME CITIES

Station	Number of samples	Correlation coefficient (RSN-NASN)	NASN ($\mu\mu c/m^3$)	RSN ($\mu\mu c/m^3$)	Ratio $\left(\frac{NASN}{RSN}\right)$
Boise, Idaho	21	0.97	6.4	4.9	1.3
Denver, Colo	17	0.91	7.2	6.6	1.1
Honolulu, Hawaii	20	0.16	7.6	2.4	3.2
Phoenix, Ariz	17	0.95	14.1	8.4	1.7
Salt Lake City, Utah	21	0.44	7.9	8.6	0.9
Seattle, Wash	13	0.92	5.1	5.7	0.9

in local meteorological conditions and in the elevation of the samplers. The cities concerned in this group are Seattle, Phoenix, Denver, Boise, Salt Lake City, and Honolulu. The results of this bivariate analysis are presented in table 2. Figure 2 illustrates the respective lines of regression (lines of best fit). NASN results are an average of 1.5 times greater than the RSN results.

With the exception of Salt Lake City and Honolulu, the correlation coefficients are in good agreement with those obtained from data on samples taken from cities in which the samplers were located at the same site. In these two exceptional cases, the low correlation coefficients show that factors other than sampling and laboratory procedures may be responsible to a greater degree for variations in the results obtained by these two programs. More specific information on the topography, weather conditions at the time each sample was taken, the elevation of the collector, and individual environmental variations at the Salt Lake City and Honolulu stations would be necessary to arrive at further conclusions as to what factors are of greatest significance in influencing the variations in results obtained from these two programs.

In conclusion, the surface air fission product gross beta concentrations reported by the NASN were, on the average, about 1.5 times those reported by the RSN. This difference in observed activities appears to be due primarily to sampling and counting techniques for the seven stations where the collectors stand side by side, and for four of the six stations where the samplers are in different locations in the same city. In the case of two stations (Salt Lake City and Honolulu) environmental factors such as differences in station location (meteorology and topography) play a greater role than at the other stations investigated.

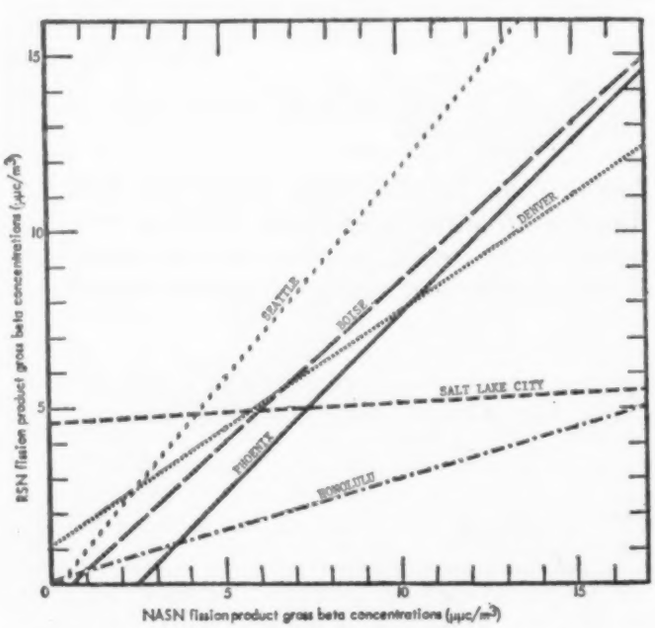

FIGURE 2.—STATISTICAL LINES OF BEST FIT (LINEAR REGRESSIONS), NASN AND RSN—DIFFERENT LOCATIONS

A Comparison of Data for Cincinnati Stations of NASN and RSN

The Sanitary Engineering Center is in the unique position of performing surface air fission product gross beta determinations for the National Air Sampling Network, and for the station in Cincinnati that had been reporting as a part of the Radiation Surveillance Network.

Sampling and laboratory techniques employed by the NASN are described in the first part of this discussion. A minor change in the counting procedure was instituted in June 1960. Since that time, the air filters are counted two days after the receipt of the filter, and there is no attempt to extrapolate back to the date of collection.

The sampling and laboratory techniques of the RSN station located in Cincinnati, differ appreciably from those employed by the NASN and those employed by the Central RSN laboratory in Washington, D.C. This variation has been introduced because this station conducts their own analyses for surface air fission product gross beta concentrations as well as for radon and thoron concentrations in the atmosphere. The radon and thoron data are discussed elsewhere (*4*).

The RSN sampler at Cincinnati, Ohio, consists of a self-lubricating vacuum pump with a sampling rate of 1 to 2 cfm. The volume of air filtered in a normal 24 hour sampling period is approximately 28 to 30 cubic meters. Air particulates are collected on a 47 mm diameter membrane filter whose pore size is 0.80 micron (*4*). Fission product gross beta concentrations are determined two days [1] after the end

[1] Subsequently changed to four days.

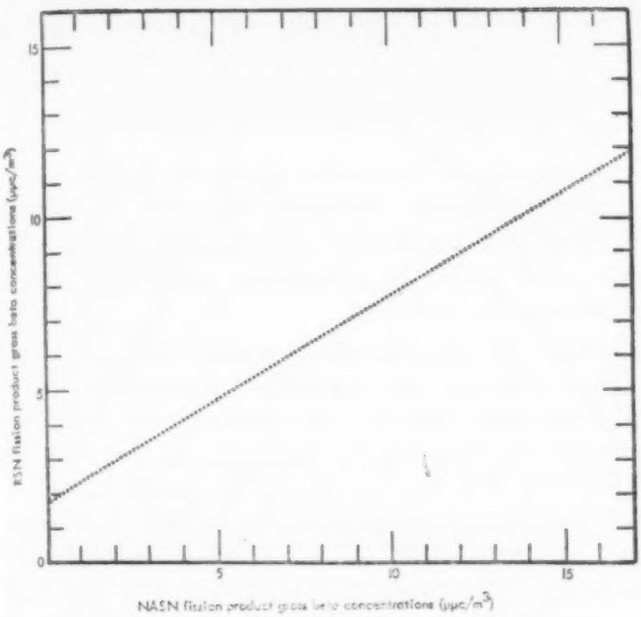

FIGURE 3.—STATISTICAL LINES OF BEST FIT (LINEAR REGRESSIONS), NASN AND RSN—CINCINNATI, OHIO

of the sampling period, and no extrapolation is made to the date of collection. The filters are placed on a 2″ diameter aluminum planchet and ashed. The gross beta activity is measured by placing the planchet in a 2″ diameter internal proportional counter (NMC–PC3A). The overall efficiency for samples with a negligible solids content is 55–75 percent (depending on the beta energies). A uranium oxide source is used as a secondary standard (*2*). The secondary source is covered with an aluminum foil to shield out the alpha activity.

The NASN sampler was located on the roof of the police station at 417 Lincoln Park Drive in 1958 and 1959, and on the roof of the nearby Cincinnati Public Library in 1960. The RSN station is located on the second floor of the Robert A. Taft Sanitary Engineering Center approximately four miles from the NASN sampler. Therefore, local climatological and topographical factors, as well as sampling and laboratory techniques, will influence the levels of radioactivity reported by the respective sampling programs.

The arithmetic mean for the NASN surface air fission product gross beta concentration for this period is 5.5 $\mu\mu c/m^3$; the corresponding value for RSN results is 5.9 $\mu\mu c/m^3$. The ratio of the mean NASN values to the RSN values is 0.9. The correlation coefficient (RSN–NASN) is 0.69. The corresponding statistical line of best fit (regression line) for the RSN versus NASN results is presented in figure 3.

The correlation coefficient obtained in this study is less than the average correlation coefficient for stations at which the samplers were at the same location, but still within the range of values reported for these stations. A comparison to those stations where the samplers were at different locations shows that the correlation coefficient for the Cincinnati data is lower than those at four of the six stations, but higher than the correlation coefficient for Salt Lake City and Honolulu.

In conclusion, laboratory and sampling techniques, as well as the sampler location, influence surface air fission product gross beta results. The degree to which these variables influence the results has not been determined by this study, nor has there been an attempt to define the effects of specific factors in the above variables which influence differences in such measurements.

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High Altitude Sampling Program

Defense Atomic Support Agency, Department of Defense

This is the first of a series of interpretive reports on the Department of Defense High Altitude Sampling Program (HASP). Without going into extensive detail this report will provide a broad outline of the scope of the program, the salient features and implications of the results obtained by the program, and the major conclusions to be drawn therefrom. Future reports in this series will highlight some of the specific facets of the program.

In this program, U-2 aircraft operated by the Strategic Air Command have collected particulate debris on filter papers (IPC–1478) which were especially developed to have both high porosity and high collection efficiency. (*1*) Radiochemical analyses of these samples has been performed at Isotopes Inc., Westwood, N.J. (*2–4*) Figure 1 shows the HASP network. In 1957, north-south sampling was established in the Northern Hemisphere. During 1958 operations were transferred to the Southern Hemisphere, and 1959 marked the termination of the active phase of HASP with major sampling resumed in the Northern Hemisphere. Continued semiannual spot checks are being made at 4 locations extending from Australia to Alaska.

FIGURE 1.—HASP FLIGHT TRACKS

Since the stratospheric winds tend to blow either easterly or westerly, depending upon latitude and altitude, the north-south network allows representative samples to be taken. Since the U-2 has an operating range of up to 3600 miles and an altitude capability of 70,000 feet, over one-half of the stratosphere can be sampled. Extrapolation up to 100,000 feet has been made using samples collected by balloons. Since each aircraft is capable of collecting 10 samples on each flight, and 8 flights per week have been scheduled, each point in this extensive network can be visited at least twice a month. Over 4,000 samples were collected between August 1957 and May 1960. These samples afforded a unique opportunity to study in detail the mixing of radioactive debris within the stratosphere and the interchange of debris between the stratosphere and the troposphere.

A number of isotopes have been studied during the course of the HASP program, but the major emphasis has been placed on strontium-90. Reasons for selecting this isotope include: (a) its relatively great abundance in fission products, (b) its half-life of 28 years which is long compared to the meteorological processes it is used to trace, (c) its convenient radiochemical characteristics, and finally (d) the fact that strontium-90 is probably the greatest single source of an internal biological hazard in world-wide fallout.

Figure 2 shows the distribution of strontium-90 concentrations in a vertical cross-section of the atmosphere. The horizontal scale is latitude plotted on a sine scale from pole to pole. The vertical scale is representative of altitude. The dark lines show the mean location of the tropopause, or boundary line between the troposphere and the stratosphere. From a meteorological point of view, these two regions are quite different. The troposphere, or lower atmosphere, is relatively turbulent

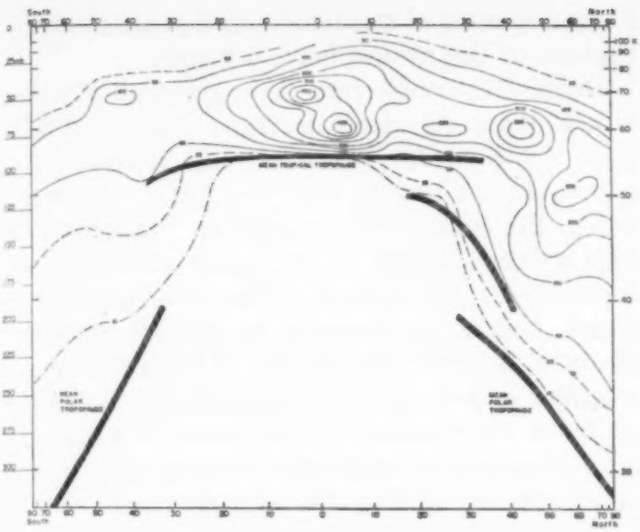

FIGURE 2.—MEAN STRONTIUM-90 DISTRIBUTION (dpm/10³SCF) DURING NOVEMBER 1957–DECEMBER 1958

and is the region which contains all the "weather" phenomena. The stratosphere, on the other hand, is ordinarily relatively quiet and vertical mixing processes are inhibited. The boundary between the two regions, the tropopause, has discontinuities in the mid-latitude regions and is lower in the polar regions than in the tropics. The height of the tropopause is subject to seasonal as well as daily fluctuations, especially in the polar regions. While radioactivity in the troposphere is ordinarily washed out by rainfall within a few weeks, debris injected into the stratosphere may persist for years.

Since the time period shown in figure 2 marked a year of active weapons testing (1958), relatively steep concentration gradients are noted. The high concentrations in the lower equatorial region are due to US and UK testing, and the high concentrations in the lower northern stratosphere are the results of Soviet testing. An additional source of debris (not shown since it is well above the sampling range even of balloons) is from two high altitude, rocket-launched, megaton-range weapons which injected their debris into the very high atmosphere. Concentrations in the troposphere are low compared to the stratosphere since material entering this region is continually being removed by the scavenging action of rainfall.

Between 1958 and mid-1960, the situation changed in a rather marked manner because there were no large tests. The debris deposited in the lower stratosphere was gradually removed. Figure 3 shows the situation in early 1960. Notice there is now a minimum in the tropical region. The hot clouds in the northern polar region have also vanished. The highest concentrations are now found in the highest latitudes and at the highest altitudes. These high concentrations in part represent debris, initially injected into the high equatorial stratosphere by the 1958 rocket shots, which has moved poleward and then downward. During the polar winter night, the temperature structure of the stratosphere alters, and strong vertical mixing is promoted. High altitude debris is brought down during this time, and produces the distribution seen.

By adding up all the strontium-90 determinations derived by the HASP network, and using balloon data for extrapolation, the stratospheric burden during a selected time interval can be calculated (*5*). Table 1 provides a crude estimate of the inventories in the Northern and Southern Hemispheres during 1958, early and late 1959, and early 1960. The amounts injected above 100,000 feet have never been measured and, consequently, the estimates of concentrations in the highest region are somewhat conjectural. The values shown in parentheses are not measured values but educated guesses. Several features can be noted. The Northern Hemispheric stratosphere had more than twice as much strontium as that of the Southern Hemisphere in 1958, but by early 1960 its burden was only 50% greater. This tendency was caused by several factors. First, the Soviet debris in the Northern Hemisphere fell out

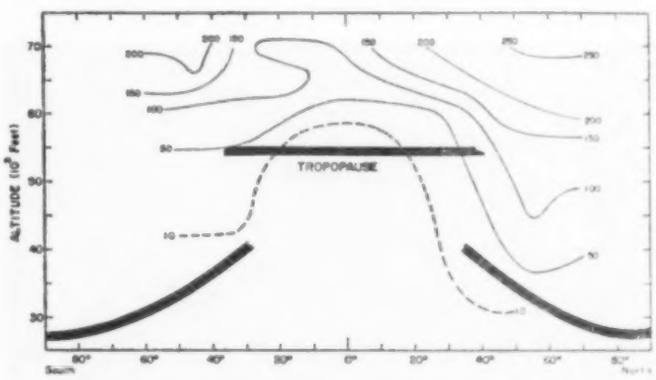

FIGURE 3.—STRATOSPHERIC DISTRIBUTION OF STRONTIUM-90 (dpm/10³SCF) DURING JANUARY–JUNE 1960

TABLE 1.—AVERAGE STRONTIUM-90 INVENTORIES
[Megacuries]

Northern Hemisphere

	1958	Early 1959	Late 1959	Early 1960
Highest Region	(.20)	(.20)	(.17)	(.13)
Balloon Region	.15	.27	.30	(.25)
HASP Region	.61	.38	.33	.37
Total	.96	.85	.80	.75

Southern Hemisphere

Highest Region	(.20)	(.19)	(.16)	(.12)
Balloon Region	.11	.15	(.17)	(.13)
HASP Region	.22	.13	(.16)	.27
Total	.53	.47	.49	.52

World Total

	1.49	1.32	1.29	1.27

quickly in early 1959. Second, there was probably some mixing southward across the equator.

In addition to shedding light on the amount of debris in the stratosphere, the HASP program has been able to delineate the rate of departure of this material from the stratosphere. The residence time of the debris is a function of the latitude and altitude of the injection. In addition, seasonally affected movements within the stratosphere influence the residence time. For instance, poleward mixing from the equatorial regions is faster during the winter, as is vertical mixing within the polar stratosphere (especially at the highest latitudes). Departure of debris from the stratosphere can be characterized fairly well by assigning half-residence times as follows: lower polar stratosphere, 6 months; lower equatorial and higher polar stratosphere, 1 year; higher equatorial stratosphere, 3 years; highest regions of the atmosphere, 6 years.

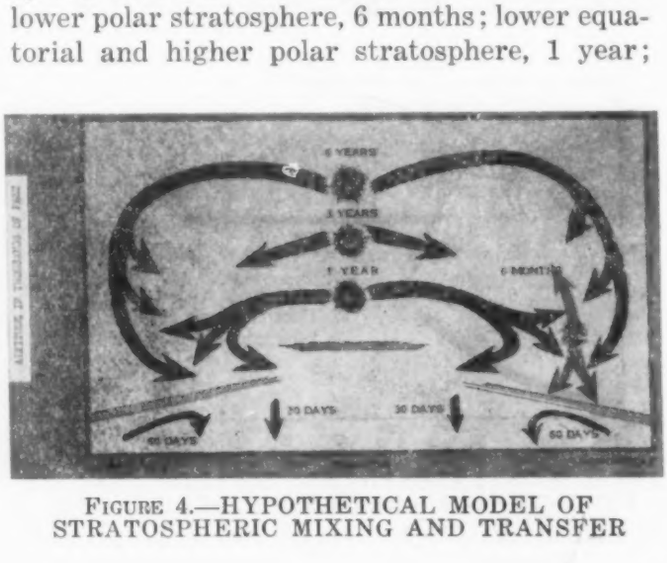

FIGURE 4.—HYPOTHETICAL MODEL OF STRATOSPHERIC MIXING AND TRANSFER

Debris injected into the tropical regions mixes poleward along surfaces that gradually slope downward. There is very little vertical mixing in the tropics and very little movement across the equatorial tropopause. Greater vertical mixing occurs in the polar stratosphere, especially in the vicinity of the tropopause gap which marks the location of the jet streams. Material injected into the top of the atmosphere is presumed to mix horizontally to a fairly uniform distribution within about 1 year and is then subject to downward mixing only in the polar regions during the winter night.

Movement into the troposphere may occur through the tropopausal gap and across the polar tropopause as it rises to a higher average elevation during the springtime. Since stratospheric processes increase the concentrations in the lower stratosphere during the winter, fallout on the ground is greatest during the spring (*6*), (*7*). Little interchange occurs during the autumn when the tropopause starts to lower and the gap shifts toward the equator. Since the debris departs from the stratosphere mainly in the temperate regions where there is a rainy belt (especially in springtime), the highest concentrations of fallout appear in the 30°–60° latitude band. In addition, vertical motion through the tropopause can bring down material. Any material brought across the tropopause at high latitudes mixes toward the Equator in the troposphere and also is scavenged by the mid-latitude rains.

In conclusion, it is seen that the HASP program has fairly well delineated the role that the stratosphere plays in the distribution of world-wide fallout. Total amounts in the stratosphere have been measured as well as their rates and locations of departure. As a result, a reconstruction of the past history of weapons testing can be made. Since the yield, location, and environment of past tests are fairly well known, as are the stratospheric injection rates and departure rates, we can plot the lower stratospheric inventory as a function of time. This is represented by the lower curve of Figure 5. Notice the two major peaks due to the high yield test series held in 1954 and 1958. For comparison, the "HASP inventories" are superimposed. These inventories are the sum of the

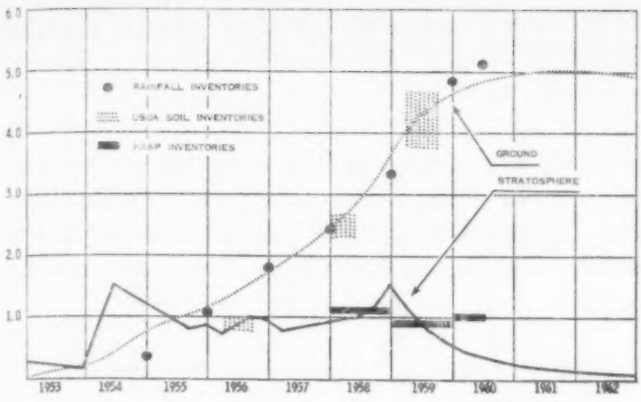

FIGURE 5.—STRONTIUM-90 INVENTORY

values shown in Table 1 for the HASP and Balloon regions. The apparent increase in the 1960 inventory is due to the influx of material from the high yield rocket shots of 1958 into the sampling regions. The upper curve shows the accumulation predicted in surface fallout from stratospheric debris from all the nuclear tests prior to 1959 (including material from the high yield rocket shots). Notice that the rate of fallout was greatest during the spring of 1959. Notice, too, that the peak concentration of strontium-90 on the ground has apparently been reached; that is, the rate of fallout is less than the rate of decay of the strontium-90 presently in the soil (2½% per year). Since concentrations of strontium-90 in food have tended to follow the rate of fallout more closely than the total amounts in the soil, the peak concentrations in food occurred over a year ago.

Soil and rainfall inventories measured by other programs confirm the prediction of total inventory made by HASP to within 15 to 20% (*8*). In addition, many of the details of the surface collection programs compare well with those of HASP, and, as a result, a well integrated picture of the meteorological processes involved in world-wide fallout has emerged.

While the ecological and biological problems involved in evaluating the hazards from world-wide fallout introduce considerable uncertainty, the meteorological facts that are known provide fairly well-defined boundary conditions. Table 2 provides a basis of comparison of the hazard from fallout from past weapons tests (*9*). Essentially the basic yardstick for comparison of the hazard is that provided by the natural background radiation.

TABLE 2.—RADIATION EXPOSURE FROM NUCLEAR WEAPONS TESTS

[in millirem]

Whole body dose from:	1959 (1 yr)	1955–1985 (30 yr)	1955–2025 (70 yr)
Internal C^{14}	0.4	5	8
Internal Cs^{137}	2	20	30
External Cs^{137}	1	20	30
External Zr, Ru, Ce	20	30	30
Total	23	75	98
Natural Background (cosmic rays, rocks, etc.)	100	3,000	7,000
Additional bone dose to children from:			
Internal Sr^{90}	7	75	103
Population RPG for Sr^{90}	170	5,000	12,000

It is seen that whole body irradiation comes from an internal exposure of cesium-137 and, to a lesser extent, carbon-14, as well as an external exposure from cesium-137 and shorter lived radioisotopes. During the period of greatest weapon testing, the dose level can rise to 20% of background. However, in the absence of future atmospheric testing, the 30-year genetically-significant dose will be no more than a small percent of background.

Strontium-90 provides the single greatest source of concentrated long-term exposure to a particular organ of the body, namely the skeleton. It can be seen that the lifetime dose from this source when added to the whole body dose (to which, of course, the bones are exposed) is still only a small percent of the natural background expected during the same period.

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Radioactivity Measurements in Air

U.S. Naval Research Laboratory

Radioactivity measurements of air-filter samples collected at various sites near the 80th Meridian (West) are made by the U.S. Naval Research Laboratory under a program partially financed by the Atomic Energy Commission.

The daily record of fission product beta activity during May 1961 is presented in table 1, and the radioactivity profiles for the same month and the first quarter 1961 are shown in figure 1. This figure illustrates the data plotted in semilogarithmic coordinates. The abscissa is expressed in micromicrocuries per cubic meter of surface air. The concentrations in table 1 are expressed in disintegrations per minute per cubic meter of air at the collecting site (2.2 disintegrations per minute per cubic meter equals 1 micromicrocurie per cubic meter).

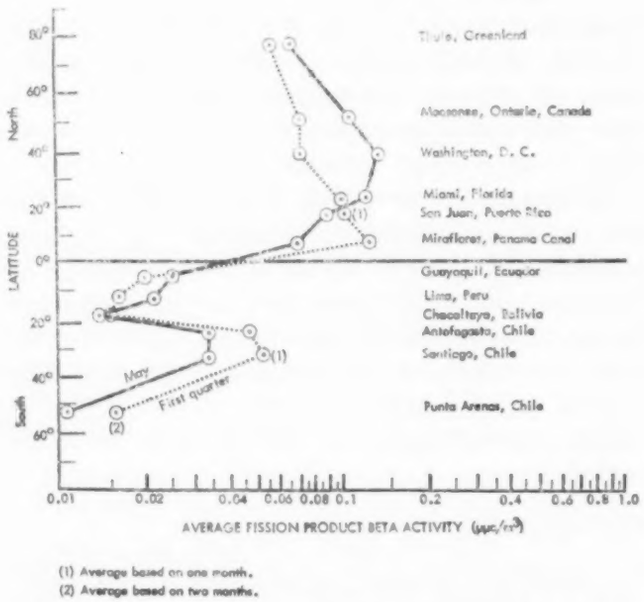

FIGURE 1.—PROFILE OF BETA ACTIVITY, AVERAGE MEASUREMENTS OF SURFACE AIR AT STATIONS NEAR THE 80TH MERIDIAN (WEST), FIRST QUARTER AND MAY 1961

FIGURE 2.—ATMOSPHERIC RADIOACTIVITY SAMPLING STATIONS NEAR THE 80TH MERIDIAN (FROM NRL REPORT 5359, SEPT. 1959)

TABLE 1.—DAILY RECORD OF FISSION PRODUCT BETA ACTIVITY COLLECTED BY AIR FILTRATION, MAY 1961

[Disintegrations per minute/cubic meter]

Day	Punta Arenas, Chile	Puerto Montt, Chile	Santiago, Chile	Antofagasta, Chile	Chacaltaya, Bolivia	Lima, Peru	Guayaquil, Ecuador	Miraflores, Panama Canal	San Juan, Puerto Rico	Mauna Loa, Hawaii	Miami, Florida	Washington, D. C.	Moosonee, Ontario, Canada	Thule, Greenland
1	0.02	----------	0.03	0.10	0.05	0.04	0.05	0.11	0.21	0.12	0.48	0.28	----------	0.23
2	0.01	----------	0.09	0.08	0.05	0.05	0.04	0.12	0.30	0.10	0.33	0.33	0.18	0.14
3	0.01	----------	0.09	0.08	0.05	0.05	0.04	0.12	0.30	0.10	0.33	0.33	0.18	0.14
4	0.04	----------	0.18	0.06	0.04	0.05	0.04	0.25	0.22	0.14	0.21	0.18	0.18	0.13
5	0.04	----------	0.07	0.06	0.04	0.05	0.04	0.25	0.22	0.14	0.21	0.18	0.26	0.13
6	0.02	----------	0.07	0.10	0.03	0.02	0.03	0.19	0.19	0.26	0.32	0.28	0.41	0.21
7	0.02	----------	0.07	0.10	0.03	0.02	0.03	0.19	0.19	0.26	0.32	0.28	0.41	0.21
8	0.02	----------	0.07	0.07	0.03	0.02	0.03	0.19	0.19	0.26	0.32	0.28	0.41	0.21
9	----------	----------	0.07	0.07	0.03	0.02	0.04	0.19	0.11	0.31	0.29	0.22	0.27	0.19
10	----------	----------	0.07	0.07	0.03	0.02	0.04	0.19	0.11	0.31	0.29	0.22	0.27	0.19
11	----------	----------	0.02	0.08	0.02	0.05	0.04	0.15	0.22	0.30	0.36	0.14	0.34	0.16
12	----------	----------	0.02	0.08	0.02	0.05	0.04	0.15	0.22	0.30	0.36	0.14	0.34	0.16
13	----------	----------	0.10	0.10	0.02	0.07	0.01	0.13	0.20	0.13	0.29	0.11	0.15	0.17
14	----------	----------	0.10	0.10	0.02	0.07	0.01	0.13	0.20	0.13	0.29	0.11	0.15	0.17
15	----------	----------	0.10	0.10	0.02	0.07	0.01	0.13	0.20	0.13	0.29	0.11	0.15	0.17
16	----------	----------	0.05	0.12	0.02	0.09	----------	0.14	0.21	0.14	0.37	0.31	0.19	0.14
17	----------	----------	0.05	0.12	0.02	0.09	----------	0.14	0.21	0.14	0.37	0.31	0.19	0.14
18	----------	----------	0.05	0.02	0.02	0.04	----------	0.16	0.19	0.19	0.42	0.52	0.31	0.14
19	----------	----------	0.05	0.02	0.03	0.04	0.07	0.16	0.19	0.19	0.42	0.52	0.31	0.14
20	----------	----------	0.07	0.08	0.03	0.05	0.07	0.15	0.22	0.21	0.33	0.41	0.25	0.09
21	----------	----------	0.07	0.08	0.03	0.05	----------	0.15	0.22	0.21	0.33	0.41	0.25	0.09
22	----------	----------	0.07	0.08	0.03	0.05	----------	0.15	0.22	0.21	0.33	0.41	0.25	0.09
23	----------	----------	0.14	0.07	0.03	0.06	----------	0.17	0.20	0.22	0.31	0.31	0.18	0.13
24	----------	0.02	0.14	0.07	0.03	0.06	0.06	0.17	0.20	0.22	0.31	0.31	0.18	0.13
25	----------	0.02	0.09	0.08	0.03	0.05	0.06	0.09	0.20	0.33	0.13	0.63	0.18	0.12
26	----------	0.02	0.09	0.08	0.03	0.05	0.06	0.09	0.20	0.33	0.13	0.63	0.06	0.12
27	----------	0.05	0.07	0.06	0.04	0.03	----------	0.13	----------	0.26	0.13	0.24	0.21	0.13
28	----------	0.05	0.07	0.06	0.04	0.03	----------	0.13	----------	0.26	0.13	0.24	0.21	0.13
29	----------	0.05	0.07	0.06	0.04	0.03	----------	0.13	----------	0.26	0.16	0.24	0.21	0.13
30	----------	0.05	----------	0.08	0.05	0.07	----------	0.18	----------	0.12	0.20	0.51	0.30	0.11
31	----------	0.05	----------	0.08	0.05	0.07	----------	0.18	----------	0.12	0.20	0.51	0.30	0.11
Mean (dpm/m³)	0.022	0.039	0.077	0.078	0.032	0.049	0.040	0.155	0.205	0.206	0.289	0.313	0.243	0.147
Mean (μμc/m³)	0.010	0.018	0.035	0.035	0.014	0.022	0.018	0.070	0.092	0.093	0.130	0.141	0.109	0.066

National Air Sampling Network

Division of Air Pollution, Public Health Service

The Public Health Service developed its National Air Sampling Network in 1953 to secure basic data on the nature and extent of air pollution throughout the United States, and to detect trends in levels of pollution with respect to time, location, population density, climate, and other factors associated with air quality.

The current basic network consists of 103 sampling stations operating every year in 66 large cities and 37 nonurban areas. In addition to these every-year stations, 126 cities have stations which operate every other year. Thus, there are 229 sampling stations in all, of which about 166 are active in any given year. A list of National Air Sampling Network Stations appeared in the May 1960 issue of *Radiological Health Data.*

The network stations are manned by cooperating federal, state, and local agencies. Twenty-four hour samples of suspended particulate matter representing approximately 2000 cubic meters of air are collected on glass fiber filters on a bi-weekly random sampling schedule. The analyses of these samples include the measurement of total quantity of suspended particulate matter, the organic matter soluble in benzene, and gross beta radioactivity. Selected samples are analyzed also for nitrates and sulfates, and for a number of metals.

Quarterly reports of individual sample data and annual summaries are distributed to all participating agencies and state health departments. A comprehensive report on the first

five years of operation of the Network is contained in the publication, *Air Pollution Measurements of the National Air Sampling Network*, Public Health Service Publication No. 637, 1958.

Gross beta activity, by states for the years 1953 through 1958 was submitted by Dr. F. J. Weber, Chief of the Division of Radiological Health, Public Health Service, in testimony before the Joint Committee on Atomic Energy Hearings on Fallout from Nuclear Weapons Tests, Vol. 1, May 1959, pages 173–185.

Previous data on gross beta activities of particulates in air were published in *Radiological Health Data*, Volume I, Numbers 7 and 8; and Volume II, Numbers 1, 4, and 7. Data for the second quarter 1961 are presented in table 1.

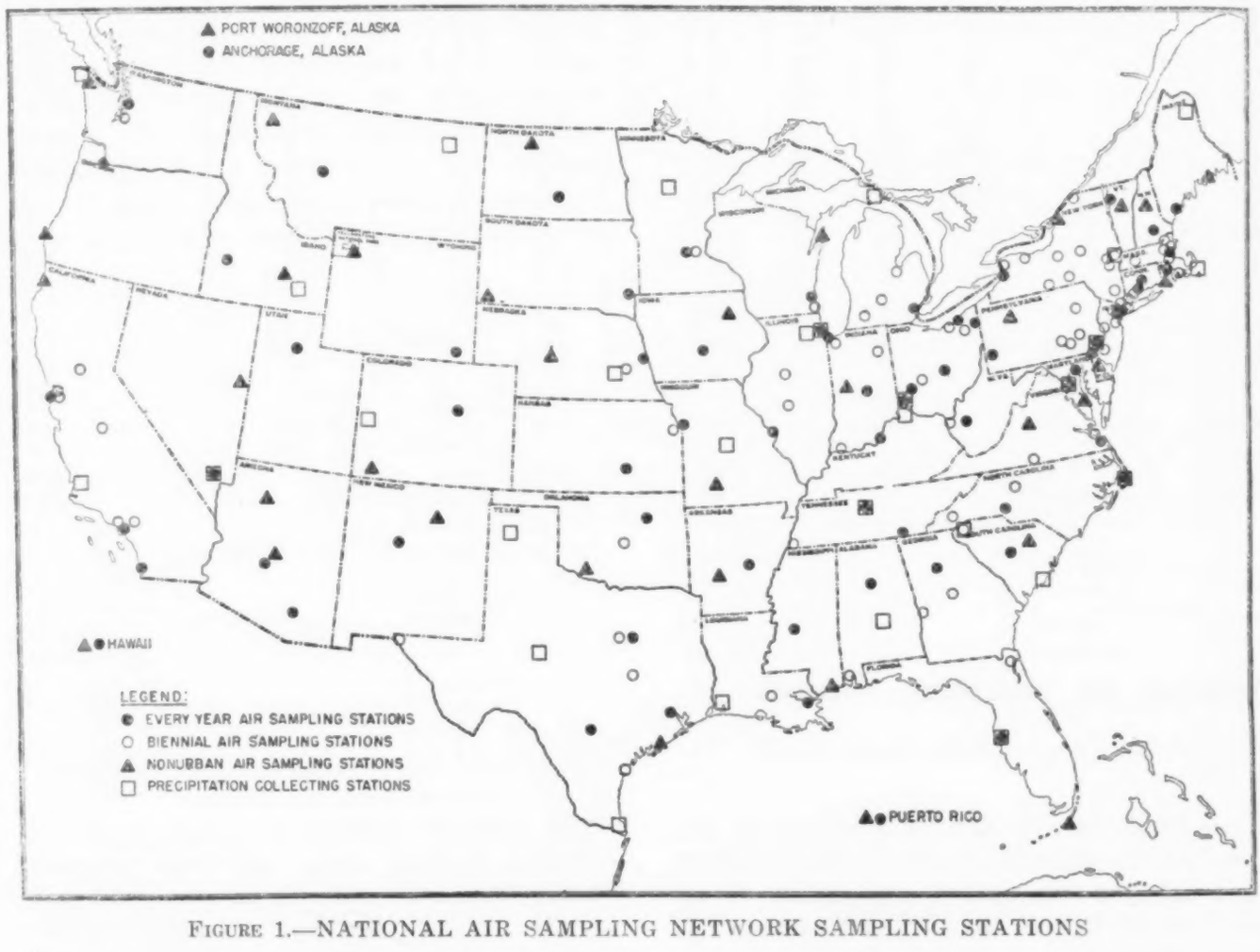

FIGURE 1.—NATIONAL AIR SAMPLING NETWORK SAMPLING STATIONS

TABLE 1.—GROSS BETA RADIOACTIVITY IN AIR, SECOND QUARTER 1961

($\mu\mu$c per cubic meter)

Station location	Number of samples	Minimum	Maximum	Average	Station location	Number of samples	Minimum	Maximum	Average
Acadia Nat. Pk., Maine [1]	6	<0.1	0.6	0.2	Bethlehem, Pa.	7	0.1	0.1	0.1
Akron, Ohio	7	0.1	0.2	0.1	Binghamton, N. J.	7	0.1	0.2	0.1
Albany, N. Y.	6	<0.1	0.3	0.1	Birmingham, Ala.	6	0.1	0.2	0.2
Albuquerque, N. M.	5	0.1	0.1	0.1	Bismarck, N. D.	7	0.1	0.3	0.1
Allentown, Pa.	5	<0.1	0.2	0.1	Black Hills Frst., S. D.[1]	4	0.1	0.2	0.1
Altoona, Pa.	2	<0.1	0.1	0.1	Boise, Idaho	6	0.1	0.4	0.2
Anchorage, Alaska	7	<0.1	0.2	<0.1	Boston, Mass.	6	<0.1	0.3	0.2
Atlanta, Ga.	4	0.1	0.2	0.2	Brockton, Mass.	7	<0.1	0.4	0.1
Atlantic City, N. J.	6	0.1	0.2	0.1	Burlington, Vt.	5	0.1	0.3	0.1
Augusta, Ga.	7	0.1	0.3	0.2	Butte County, Idaho [1]	6	0.1	0.2	0.2
Austin, Tex.	7	0.1	0.2	0.1	Calhoun County, Tex.[1]	3	0.1	0.3	0.2
Baltimore, Md.	7	0.1	0.6	0.2	Calvert County, Md.[1]	6	<0.1	0.2	0.1
Beaumont, Tex.	6	0.1	0.2	0.1	Cambridge, Mass.	4	0.1	0.2	0.2
Berkeley, Calif.	7	<0.1	0.1	0.1	Canton, Ohio	6	0.1	0.4	0.2

TABLE 1.—GROSS BETA RADIOACTIVITY IN AIR, SECOND QUARTER 1961—Continued

[$\mu\mu$c per cubic meter]

Station location	Number of samples	Minimum	Maximum	Average	Station location	Number of samples	Minimum	Maximum	Average
Cape Hatteras, N. C.[1]	5	<0.1	0.4	0.1	Montezuma County, Col.[1]	7	0.1	0.5	0.2
Cape Vincent, N. Y.[1]	5	0.1	0.2	0.1	Mt. Vernon, N. Y	5	<0.1	0.2	0.1
Charlotte, N. C	6	0.1	0.3	0.2	Nashville, Tenn	6	0.1	0.3	0.2
Charleston, S. C	7	0.1	0.3	0.2	New Albany, Ind	6	0.1	0.3	0.1
Charleston, W. Va	6	0.1	0.3	0.2	New Bedford, Mass	6	<0.1	0.3	0.1
Chattanooga, Tenn	6	0.1	0.3	0.2	New Britain, Conn	6	<0.1	0.2	0.1
Cherokee County, Okla.[1]	6	<0.1	0.5	0.2	New Haven, Conn	7	0.1	0.4	0.2
Cheyenne, Wyo	6	0.1	0.3	0.2	New Orleans, La	6	0.1	0.3	0.2
Chicago, Ill	7	0.1	0.3	0.2	New Rochelle, N. Y	6	<0.1	0.2	0.1
Cincinnati, Ohio	6	<0.1	0.2	0.1	New York, N. Y	7	0.1	0.1	0.1
Clallum County, Wash.[1]	6	<0.1	0.1	<0.1	Newark, N. J	6	<0.1	0.2	0.1
Clarion County, Pa.[1]	5	<0.1	0.2	0.1	Niagara Falls, N. Y	5	0.1	0.5	0.2
Clayton County, Iowa [1]	3	0.1	0.2	0.2	Norfolk, Va	6	<0.1	0.2	0.1
Cleveland, Ohio	6	0.1	0.5	0.2	Oakland, Calif	4	0.1	0.1	0.1
Colfax County, N. Mex.[1]	7	0.1	0.4	0.2	Oklahoma City, Okla	7	0.1	0.4	0.2
Columbia, S. C	6	<0.1	0.3	0.2	Omaha, Nebr	6	0.1	0.5	0.2
Columbus, Ohio	6	0.1	0.4	0.2	Orange County, Vt.[1]	6	<0.1	0.5	0.2
Coos County, N. H.[1]	5	<0.1	0.4	0.1	Orlando, Fla	4	<0.1	0.3	0.2
Curry County, Oreg.[1]	4	<0.1	0.1	0.1	Paterson, N. J	4	<0.1	0.3	0.2
Dallas, Tex	7	0.1	0.3	0.2	Philadelphia, Pa	6	<0.1	0.4	0.2
Davenport, Iowa	6	0.1	0.3	0.2	Phoenix, Ariz	6	0.1	0.5	0.2
Dayton, Ohio	6	0.1	0.3	0.2	Pittsburgh, Pa	6	0.1	0.7	0.2
Dearborn, Mich	4	0.1	0.2	0.1	Portland, Maine	7	<0.1	0.2	0.1
Denver, Col	5	0.1	0.2	0.2	Portland, Oreg	6	<0.1	0.4	0.2
Des Moines, Iowa	6	0.1	0.2	0.2	Portsmouth, Va	6	<0.1	0.2	0.1
Detroit, Mich	7	0.1	0.2	0.1	Providence, R. I	6	<0.1	0.3	0.1
Door County, Wis.[1]	4	0.1	0.3	0.2	Pt. Woronzof, Alaska [1]	4	<0.1	0.2	0.1
Duluth, Minn	7	0.1	0.2	0.1	Raleigh, N. C	5	<0.1	0.2	0.1
East Chicago, Ind	8	<0.1	0.2	0.1	Richland County, S. C.[1]	7	0.1	0.5	0.2
East St. Louis, Ill	6	0.1	0.3	0.1	Richmond, Va	5	<0.1	0.1	0.1
Elmira, N. Y	7	<0.1	0.2	0.1	Roanoke, Va	7	<0.1	0.3	0.1
Erie, Pa	6	0.1	0.3	0.1	Rochester, N. Y	7	0.1	0.2	0.1
Eugene, Oreg	6	<0.1	0.2	0.1	Rockford, Ill	6	<0.1	0.3	0.2
Flint, Mich	7	0.1	0.3	0.2	Salt Lake City, Utah	4	0.1	0.2	0.2
Galveston, Tex	7	<0.1	0.2	0.1	San Antonio, Tex	5	0.1	0.3	0.2
Glacier Nat Pk., Mont.[1]	7	0.1	0.5	0.2	San Bernardino, Calif	6	0.1	0.4	0.2
Glen Cove, N. Y	6	0.1	0.2	0.1	San Diego, Calif	6	0.1	0.7	0.3
Glendale, Calif	5	<0.1	0.2	0.1	San Francisco, Calif	7	<0.1	0.3	0.1
Grand Canyon Pk., Ariz.[1]	5	0.1	0.3	0.2	San Jose, Calif	7	<0.1	0.1	0.1
Greensboro, N. C	6	0.1	0.1	0.1	San Juan, P. R	7	<0.1	0.1	0.1
Hammond, Ind	6	0.1	0.4	0.2	Savannah, Ga	6	<0.1	0.5	0.2
Hampton, Va	6	<0.1	0.2	0.1	Schenectady, N. Y	6	0.1	0.2	0.2
Hamilton, Ohio	7	0.1	0.2	0.1	Scranton, Pa	6	<0.1	0.3	0.1
Hartford, Conn	5	<0.1	0.2	0.1	Seattle, Wash	6	<0.1	0.4	0.1
Helena, Mont	6	0.1	0.5	0.2	Shannon County, Mo.[1]	5	0.1	0.2	0.2
Honolulu, Hawaii	7	<0.1	0.2	0.1	Shenandoah Nat. Pk., Va.[1]	6	0.1	0.2	0.1
Houston, Tex	7	0.1	0.2	0.1	Shreveport, La	4	<0.1	0.2	0.1
Humboldt County, Calif.[1]	6	<0.1	0.1	<0.1	Sioux Falls, S. D	6	0.1	0.5	0.2
Indianapolis, Ind	6	0.1	0.3	0.2	South Bend, Ind	5	0.1	0.5	0.2
Jackson County, Miss.[1]	3	0.1	0.1	0.1	Spokane, Wash	6	0.1	0.5	0.2
Jackson, Mich	7	0.1	0.2	0.1	St. Louis, Mo	6	0.1	0.4	0.2
Jackson, Miss	3	0.1	0.4	0.2	St. Paul, Minn	6	<0.1	0.3	0.1
Jersey City, N. J	5	<0.1	0.1	0.1	St. Petersburg, Fla	7	0.1	0.3	0.2
Johnstown, Pa	7	0.1	0.3	0.2	Stockton, Calif	5	0.1	0.1	0.1
Kahaluu, Hawaii [1]	6	<0.1	0.3	0.1	Syracuse, N. Y	6	<0.1	0.1	0.1
Kansas City, Mo	6	0.1	0.2	0.1	Tampa, Fla	6	<0.1	0.5	0.2
Kent County, Del.[1]	6	<0.1	0.5	0.2	Terre Haute, Ind	5	0.1	0.4	0.2
Knoxville, Tenn	6	0.1	0.4	0.3	Thomas County, Nebr.[1]	7	0.1	0.4	0.2
Las Vegas, Nev	4	0.1	0.4	0.3	Toledo, Ohio	6	<0.1	0.3	0.1
Little Rock, Ark	6	0.1	0.2	0.1	Topeka, Kans	6	0.1	0.5	0.2
Long Beach, Calif	6	0.1	0.1	0.1	Troy, N. Y	6	<0.1	0.2	0.1
Loquillo Mtns., P. R.[1]	7	<0.1	0.4	0.1	Tulsa, Okla	4	<0.1	0.5	0.3
Los Angeles, Calif	6	0.1	0.4	0.2	Tucson, Ariz	7	0.1	0.5	0.2
Louisville, Ky	5	0.1	0.2	0.1	Utica, N. Y	7	<0.1	0.4	0.2
Lowell, Mass	6	<0.1	0.2	0.1	Ward County, N. D.[1]	7	<0.1	0.3	0.1
Madison, Wis	6	0.1	0.3	0.2	Washington County, R. I.[1]	6	<0.1	0.3	0.2
Manchester, N. H	5	<0.1	0.3	0.1	Washington, D. C	7	0.1	0.4	0.2
Maricopa County, Ariz.[1]	7	0.1	0.5	0.3	Waterbury, Conn	5	<0.1	0.2	0.1
Massena, N. Y	5	0.1	0.3	0.2	Wheeling, W. Va	2	0.1	0.1	0.1
Medford, Oreg	5	0.1	0.2	0.1	White Pine County, Nev.[1]	6	0.1	0.5	0.2
Memphis, Tenn	6	<0.1	0.3	0.1	Wichita, Kans	4	0.1	0.3	0.2
Miami, Fla	6	<0.1	0.3	0.1	Wilmington, Del	6	0.1	0.2	0.2
Milwaukee, Wis	5	<0.1	0.2	0.1	Worcester, Mass	3	<0.1	0.1	0.1
Minneapolis, Minn	7	0.1	0.2	0.1	Yellowstone Pk., Wyo.[1]	6	0.1	0.5	0.2
Montgomery, Ala	6	0.1	0.2	0.1	York, Pa	6	0.1	0.5	0.2
Montgomery County, Ark.[1]	5	<0.1	0.3	0.1	Youngstown, Ohio	6	<0.1	0.2	<0.1
Montgomery County, Ind.[1]	5	0.1	0.6	0.2					

[1] Nonurban station.

Gross Beta Radioactivity in Precipitation

Precipitation Collection Section, National Air Sampling Network
Division of Air Pollution, Public Health Service

During 1959 a precipitation collection and analysis program was established by the Weather Bureau Research Station in Cincinnati, Ohio, and the National Air Sampling Network. The collection stations are located at Weather Bureau offices or airport stations. Monthly composite samples of precipitation are collected at 30 stations and forwarded to the Network laboratory for analysis. A list of these precipitation collection stations is given below. Samples are analyzed for total solids and a large number of metals and nonmetals. In addition, samples representing 85 percent or more of the official rainfall recorded at the collecting stations are analyzed for fission product gross beta radioactivity if a large enough volume remains after the requirements for the chemical analysis have been met.

PRECIPITATION COLLECTION STATIONS

National Air Sampling Network

Alabama: Montgomery
California: Santa Maria
Colorado: Grand Junction
Florida: Tampa
Idaho: Pocatello
Illinois:
  Chicago (Midway Airport)
  Chicago (O'Hare Airport)
Louisiana: Lake Charles
Maine: Caribou
Maryland: Silver Hill
Massachusetts: Nantucket
Michigan: Saulte Ste. Marie
Minnesota: St. Cloud
Missouri: Columbia
Montana: Glasgow
Nebraska: Grand Island
Nevada: Las Vegas
New York: Albany
North Carolina: Cape Hatteras
Ohio:
  Cincinnati (research station)
  Cincinnati (airport)
Pennsylvania: Philadelphia
South Carolina:
  Charleston
  Greenville
Tennessee: Nashville
Texas:
  Brownsville
  San Angelo
  Amarillo
Virginia: Sterling
Washington: Tatoosh Island

TABLE 1.—GROSS BETA RADIOACTIVITY OF PRECIPITATION, SECOND QUARTER, 1961

Station	April		May		June	
	μμc/liter	μμc/m²	μμc/liter	μμc/m²	μμc/liter	μμc/m²
Albany, N. Y.	24	1,700	23	2,900	[a]	[a]
Amarillo, Tex.	[a]	[a]	16	1,400	[a]	[a]
Cape Hatteras, N. C.	12	900	12	1,200	9	900
Caribou, Maine	12	1,100	[a]	[a]	41	2,100
Charleston, S. C.	[a]	[a]	[a]	[a]	11	1,600
Chicago, Ill. (Midway)	[a]	[a]	[a]	[a]	39	3,200
(O'Hare)	[a]	[a]	[a]	[a]	25	2,400
Cincinnati, Ohio (Airport)	22	1,500	15	2,600	[a]	[a]
Columbia, Mo.	20	2,300	20	3,100	21	2,000
Grand Island, Nebr.	[a]	[a]	[a]	[a]	26	2,400
Grand Junction, Colo.	[a]	[a]	19	3,300	[a]	[a]
Greenville, S. C.	14	1,500	35	2,100	20	2,000
Lake Charles, La.	[a]	[a]	[a]	[a]	6	500
Montgomery, Ala.	[a]	[a]	[a]	[a]	8	800
Nantucket, Mass.	26	3,500	11	1,600	[a]	[a]
Nashville, Tenn.	[a]	[a]	15	1,900	[a]	[a]
Philadelphia, Pa.	[a]	[a]	[a]	[a]	33	1,900
San Angelo, Tex.	[a]	[a]	13	800	4	500
Sault St. Marie, Mich.	[a]	[a]	[a]	[a]	19	2,500
St. Cloud, Minn.	[a]	[a]	20	1,200	[a]	[a]
Sterling, Va.	[a]	[a]	[a]	[a]	12	1,000

[a] No data available due to low collection efficiency or inadequate sample.

SECTION II. — FOOD OTHER THAN MILK

Tri-City Diet Study

Joseph Rivera
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The Health and Safety Laboratory is continuing its dietary survey begun in March 1960 of the strontium-90 content of average diets of individuals living in New York City, San Francisco, and Chicago. The results obtained for these cities in the first and second set of samples were reported in HASL–90 (*1*) and HASL–111 (*2*) and presented in *Radiological Health Data*, Volume II, Numbers 4 and 6.

Selected foods, representing 19 food categories, are purchased at each of these three cities about every three months and are analyzed for strontium-90 and stable calcium. Using data from the U.S. Department of Agriculture, "Household Food Survey of 1955," the annual consumption by an individual can be grouped into the same 19 food categories. The annual dietary intake of strontium-90 and calcium can then be estimated by summing the contributions from each category. Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general. Hence, in the tables that follow, the values shown for food consumption may not be directly related to the original data in the source document.

The first two sets of results showed some variability in the calcium content obtained from analysis of the individual food categories. However there is a relative constancy of the average annual intake of calcium due to its strong dependence on relatively constant calcium content of milk. Therefore the analysis of food categories for stable calcium were discontinued following the second sampling. The total intake of calcium is calculated to be 383 grams with a standard deviation of less than five percent and is used to determine the strontium to calcium ratio in the total diet. Using the totals given in table 1, the following average concentrations in μμc/gm Ca may be derived for the year: New York, 10.4; Chicago, 7.9; San Francisco, 3.6.

Results for the third sampling in 1960 are reported in table 1 (*3*). The San Francisco diet continues to be much lower in strontium-90 content than the diets in New York City or Chicago.

The strontium-90 to calcium ratios of an average New York City diet in 1958 and 1959, based on the limited data reported in HASL–90, are estimated to have been 12 and 17 strontium units, respectively. Since the fallout rate in 1959 is known to have been greater than that in 1958 or that in 1960, these data confirm what is already generally known, namely that the strontium-90 contamination of foods depends to some extent on the fallout rate.

TABLE 1.—STRONTIUM-90 LEVELS OF DIET—THIRD SAMPLING

Food type	Annual consumption (kg/yr)	New York City (October 1960)		Chicago (November 1960)		San Francisco (January 1961)	
		μμc/kg	μμc/yr	μμc/kg	μμc/yr	μμc/kg	μμc/yr
Whole grain products	11	17	187	15.3	168	1.5	16
Refined grain products	37	5.7	211	5.0	185	3.9	144
Refined grain flour	43	5.0	215	5.5	237	2.0	86
Milk, liquid	221	6.2	1370	6.3	1392	1.8	398
Potatoes	45	5.5	248	1.3	58	3.7	166
Macaroni	3	7.1	21	5.0	15	2.9	9
Beans, dried	3	8.4	25	15.7	48	4.2	13
Vegetables, canned	20	5.3	106	5.8	116	1.2	24
Vegetables, fresh	43	17.6	757	6.3	271	2.0	86
Vegetables, root	17	4.8	82	3.0	51	2.8	48
Fruit, canned	26	1.3	34	1.1	29	3.5	91
Fruit juices	19	3.2	61	3.0	57	2.6	49
Fruit, fresh	68	7.9	537	4.1	279	1.8	122
Rice	3	2.2	7	0.9	3	1.7	5
Eggs	16	3.2	51	1.4	22	2.3	37
Fish, fresh	8	0.1	1	2.6	21	0.4	3
Fish, shell	1	1.2	1	0.5	1	0.3	1
Meat	73	0.9	66	0.6	44	0.6	44
Poultry	17	0.8	14	0.9	15	2.1	36
Total annual intake			3992		3012		1378

TABLE 2.—ANNUAL STRONTIUM-90 INTAKE IN VARIOUS FOOD CATEGORIES

[Estimated percent of total]

Food types	New York City			Chicago			San Francisco		
	March 1960	June 1960	October 1960	May 1960	September 1960	November 1960	March 1960	August 1960	January 1961
Whole grain products	5.2	6.5	4.7	5.4	6.0	5.6	1.6	9.0	1.2
Refined grain products	8.0	7.9	5.3	11.9	11.3	6.2	4.7	12.4	10.4
Refined grain flour	10.2	8.3	5.4	11.9	11.4	8.0	7.8	12.7	6.2
Milk, liquid	48.0	51.1	34.3	33.1	41.4	46.2	46.2	31.1	28.9
Potatoes	10.1	3.0	6.2	3.2	4.2	1.9	9.9	2.0	12.0
Macaroni	0.5	0.3	0.5	0.7	0.8	0.5	0.5	0.9	0.7
Beans, dried	0.1	0.1	0.6	0.1	0.7	1.6	0.9	0.8	0.9
Vegetables, canned	1.9	1.2	2.7	2.3	3.6	3.9	1.8	1.2	1.7
Vegetables, fresh	5.4	12.3	19.0	11.6	7.9	9.1	4.9	9.6	6.2
Vegetables, root	2.1	1.8	2.1	2.8	1.9	1.7	4.9	0.9	3.5
Fruit, canned	0.9	1.0	0.9	1.2	0.8	1.0	1.8	3.6	6.6
Fruit juices	0.7	1.2	1.5	1.6	1.3	1.9	2.2	2.8	3.6
Fruit, fresh	0.5	2.7	13.5	10.0	3.6	9.4	2.3	5.0	8.9
Rice	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.4	0.4
Eggs	3.9	0.7	1.3	1.3	1.0	0.7	2.3	2.7	2.7
Fish, fresh	0.0	0.0	0.0	0.2	0.0	0.7	0.1	0.1	0.2
Fish, shell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Meat	1.7	1.4	1.7	1.8	2.4	1.5	6.9	2.7	3.2
Poultry	0.6	0.3	0.4	0.5	1.4	0.5	0.6	1.8	2.6
Total annual strontium-90 intake (μμc)	4376	4760	3992	4074	2991	3012	2007	1349	1378

Table 2 lists the percentage contribution of each food category to the total strontium-90 intake calculated for the year, at each city, for the three sampling periods. Data presented in this form make it possible to compare variations in the relative strontium-90 contribution of different dietary constituents with time, while minimizing the obscuring effect of geographic differences. The relative importance of milk as a strontium-90 source declined in New York City and San Francisco from the first half to the second half of 1960, but this effect was not seen in Chicago. Although the Tri-City Diet Study was not designed for this purpose, it will be of interest in future sampling to note which food categories are most sensitive to the fallout rate. The dependence of different food categories on fallout rate will not be readily discernible, because foods locally purchased may not have been locally or recently produced.

REFERENCES

(1) *Quarterly Summary Report, HASL-90*, August 18, 1960.

(2) *Quarterly Summary Report, HASL-111*, April 1, 1961.

(3) Data from *Quarterly Summary Report, HASL-113*, July 1, 1961.

Radium-226 in Diet in Three U.S. Cities (*1*)

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The previous article entitled "Tri-City Diet Study," by Mr. J. Rivera, presented data concerning strontium-90 dietary concentrations in three cities, New York, Chicago, and San Francisco, for the program's third sampling period. Sampling has been conducted at approximately three month intervals.

In the process of determining strontium-89 and strontium-90 concentrations in these food samples, a purification step was introduced to remove any radium and barium present in the strontium fraction. This fraction has now been analyzed for Ra^{226}. Radium-226 concentrations were determined by the emanation of its gaseous daughter product, radon-222 from the radium-bearing fraction of the food samples collected since May 1960.

The food categories in table 1 are the same as those used to report previous strontium-90 data obtained in the Tri-City Diet Study (*2, 3*). These data are considered a preliminary summary, and a more detailed report will be published later.

REFERENCES

(*1*) Abstracted from report by same name in *Quarterly Summary Report*, HASL-113 (July 1, 1961).
(*2*) *Quarterly Summary Report*, HASL-105, Jan. 9, 1961 and *Radiological Health Data*, Vol. II, No. 4 (April 1961).
(*3*) *Quarterly Summary Report*, HASL-111, April 1, 1961 and *Radiological Health Data*, Vol. II, No. 6 (June 1961).

TABLE 1.—RADIUM-226 IN FOODSTUFFS

	New York City				Chicago				San Francisco			
	Survey No. 2 June 1960		Survey No. 3 October 1960		Survey No. 1 May 1960		Survey No. 2 September 1960		Survey No. 2 August 1960		Survey No. 3 January 1961	
	μμg/kg orig. mat'l	μμg intake per year	μμg/kg orig. mat'l	μμg intake per year	μμg/kg orig. mat'l	μμg intake per year	μμg/kg orig. mat'l	μμg intake per year	μμg/kg orig. mat'l	μμg intake per year	μμg/kg orig. mat'l	uug intake per year
Whole grain products	3.2	36	1.2	13	3.5	38	2.9	33	[b] 2.8	[b] 31	2.8	31
Refined grain products	3.2	118	1.5	54	3.3	123	2.0	76	2.9	106	2.5	94
Refined grain flour	2.7	117	1.7	74	2.4	106	2.0	84	1.34	58	0.83	36
Milk, liquid	0.25	56	0.24	54	0.24	53	0.22	49	0.22	49	0.20	44
Potatoes	2.0	90	2.5	113	1.4	64	0.77	35	[a] 1.0	[a] 46	2.0	91
Macaroni	2.1	6	1.8	5	1.6	5	1.9	6	1.2	4	1.7	5
Beans—dried	6.1	18	3.2	10	[a] 7.0	[a] 21	2.5	8	2.3	7	4.1	12
Vegetables, canned	2.2	44	0.54	11	1.8	37	1.1	22	0.91	18	1.0	20
Vegetables, fresh	2.4	105	1.2	53	2.2	97	0.57	25	0.66	28	0.84	36
Vegetables, root	3.4	57	2.3	39	[a] 2.0	[a] 34	1.8	31	[a] 2.6	[a] 44	2.4	40
Fruit, canned	0.37	10	0.37	10	1.2	31	0.26	7	0.50	13	0.73	19
Fruit juices	1.6	31	0.49	9	0.68	13	0.86	16	0.71	14	0.62	12
Fruit, fresh	1.5	99	2.8	192	1.4	92	0.57	39	0.91	62	0.65	44
Rice	1.5	5	1.0	3	0.70	2	0.37	1	0.63	2	0.80	2
Eggs	4.1	66	7.9	127	2.7	44	[b] 2.7	[b] 44	2.6	41	1.9	31
Fish, fresh	1.2	10	0.68	5	0.71	6	1.0	8	0.80	6	1.2	9
Fish, shell	1.2	1	1.1	1	2.5	3	1.7	2	2.0	2	1.0	1
Meat	0.44	32	0.47	34	0.45	32	0.64	47	0.80	59	0.55	40
Poultry	0.73	12	0.86	15	0.79	13	1.4	23	1.9	32	0 49	8
Total yearly consumption	----------	913	----------	822	----------	814	----------	556	----------	622	----------	575

[a] Data corrected by barium as well as strontium recovery.
[b] Sample missing. Paired values used for computing sums.

SECTION III. — MILK

Milk Monitoring Program

Division of Radiological Health, Public Health Service

There are two Public Health Service Milk Monitoring Programs. The original network consisted of five milkshed sampling stations. It was later expanded to twelve stations, nine of which are still active. Raw milk is spot sampled at these stations. During 1960 a processed milk sampling program of 60 stations was established. Since the sampling procedures for the raw milk sampling stations and the processed milk area sampling stations are different, they are described and reported separately. The Public Health Service Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, continues to conduct the analyses for the original network stations; the Public Health Service Southeastern Radiological Health Laboratory at Montgomery, Alabama, and the Southwestern Radiological Health Laboratory at Las Vegas, Nevada, provide analytical services for the new program.

The objectives of the two sampling programs are not the same. The original network was established to develop sampling and radiochemical analytical proficiencies under conditions which would remain similar over a period of time in regard to the source of milk. During the operation of this program it became apparent that a broader sampling program more directly related to the milk consumed by the population was necessary. The Public Health Service, Department of Health, Education, and Welfare, acted to provide facilities for this change. This resulted in the transition from the program of sampling raw milk, collected from milksheds of limited size, to a sampling program designed to be representative of the processed milk consumed in a given municipality.

In some instances, the newly designated stations are the same as those which were reported originally. The establishment of the new processed milk area sampling stations does not preclude the need for further raw milk sampling from the selected milkshed serving the same city. It is important that both networks be in operation for a sufficient period of time to provide an overlap for the purpose of a comparative study.

Because of the different sources of these samples, changes in the method of collecting samples, and the utilization of different laboratory techniques, differences were anticipated in the amounts of radioactivity in the milk under the two programs. For this reason, an investigation to determine the comparability of the two programs was begun in January 1961. This investigation covers many factors including laboratory methodology and collection methods. Until this study has been completed, and additional experience has been gained un-

der the new program, no valid interpretation can be made of any differences of radioactivity in milk samples collected under the two systems.

Publication of the data from each program will normally follow about four months after sample collection because of the time required for shipment, processing, decay product buildup, compilation of the data, and clearance and publication procedures.

Raw Milk Sampling Stations

The initial purpose of establishing this network was in keeping with the normal and continuing program of the Public Health Service to determine trends in our changing environment with respect to measuring the amounts of radioactivity in water, air, milk, and other foods. Milk was the food chosen for initial testing because it is among the most important components of the diet and is available at all seasons of the year and in all climates. A primary objective of the project was to develop effective collection systems and radiochemical analysis procedures which would make them more suitable for larger scale programs.

The criteria on which the selection of the original sampling stations was based appeared in the discussion sections of all Volume I issues of *Radiological Health Data*. For the period reported, one-gallon raw milk samples were collected from a dairy company once each month and forwarded by air parcel post to the Robert A. Taft Sanitary Engineering Center for radionuclide analyses. These samples represent between 2,000- and 90,000-gallon lots. The concentration of iodine-131, barium-140, and cesium-137 are currently being measured by gamma scintillation spectroscopy. Total radiostrontium and strontium-90 are determined following radiochemical separations. The amount of strontium-90 is calculated by measuring the buildup of the strontium-90 daughter decay product, yttrium-90, over a two-week period. Measurements are made in a low background anticoincidence beta counter. The total radioactive strontium is counted in a shielded internal proportional counter. The difference between the total strontium and strontium-90 is reported as strontium-89. Stable calcium is also determined.

The April through September 1960 issues of *Radiological Health Data* lists references for technical descriptions of analytical procedures.

Table 1 presents first quarter 1961 averages and the May 1961 data for the raw milk sampling stations.

Processed Milk Area Sampling Stations

The processed milk surveillance program will provide additional information on levels of radioactivity in milk consumed by the public. The new stations have been established in cooperation with State and local health and milk sanitation agencies. Each city has been selected to provide adequate coverage with respect to production areas and the consuming population. The emphasis of this expanded sampling and radioassay program are:

1. to measure the levels of radioactivity of the milk consumed by the public in various regions of the country by obtaining samples of pasteurized and homogenized milk at the processing plant, and
2. to provide one sampling point within each State with additional points when

TABLE 1.—RADIOACTIVITY IN MILK—RAW MILK SAMPLING STATIONS, FIRST QUARTER AND MAY 1961

[Radioactivity concentrations in μμc/liter]

Area	Calcium (gm/liter)		Strontium-90		Cesium-137		Area	Calcium (gm/liter)		Strontium-90		Cesium-137	
	First quarter	May	First quarter	May	First quarter	May		First quarter	May	First quarter	May	First quarter	May
Atlanta, Ga.	1.18	1.16	13	14	25	20	Salt Lake City, Utah	1.19	1.16	4	3	10	10
Austin, Tex.	1.16	1.15	7	2	15	<5	Spokane, Wash.	1.22	1.16	7	8	15	15
Chicago, Ill.	1.17	1.13	6	8	20	25	St. Louis, Mo.	1.26	1.24	13	23	25	35
Cincinnati, Ohio	1.21	1.17	8	11	15	15							
New York, N. Y.	1.11	1.15	9	9	20	15	Network average	1.19	1.16	8	9	15	15
Sacramento, Calif.	1.19	1.14	5	4	10	15							

Note: I^{131}, Sr^{89} and Ba^{140} are below minimum detectable limits for samples collected in May. These limits are 10 μμc/liter for I^{131} and Ba^{140} and 5 μμc/liter for Sr^{89}.

indicated by widely varying conditions of the milk supply or the need to provide coverage of large population groups.

The new network was designed to sample processed milk rather than the raw product. The sampling procedure was developed to provide a sample from one day's sales per month in a community which would be as representative of the total supply as can be achieved under practical conditions. Each sample is a composite of those plants supplying not less than 90 percent of a city's milk supply. The contribution from each plant to the total sample is approximately proportional to the volume of milk sold.

The samples from the new stations are collected with the assistance of the various State and local health and milk sanitation agencies and are shipped for analyses to either the Southwestern or Southeastern Radiological Health Laboratory. The Southeastern Radiological Health Laboratory processes samples from the 30 states generally east of the Mississippi, and the Southwestern Radiological Health Laboratory processes samples from the western states. Figure 1 shows the locations of these stations.

At the present time, radioassays for Sr^{90}, Cs^{137}, Sr^{89}, Ba^{140} and I^{131} are being performed. For the period reported, the latter three radionuclides are not presently found in milk by the current methods of detection. The lower level of detection for Sr^{89} is 5 $\mu\mu c$/ liter, and for Ba^{140} and I^{131}, 10 $\mu\mu c$/liter. Other radionuclides of concern to public health agenies will be included for assay as necessary for a more complete monitoring of the milk supply.

Table 2 presents first quarter averages for 1961 and the May 1961 data for processed milk sampling stations.

FIGURE 1.—PROCESSED MILK AREA SAMPLING STATIONS

TABLE 2.—RADIOACTIVITY IN MILK—PROCESSED MILK AREA SAMPLING STATIONS, FIRST QUARTER AND MAY 1961

[Radioactivity concentrations in $\mu\mu c$/liter]

Area	Calcium (gm/liter)		Strontium-90		Cesium-137		Area	Calcium (gm/liter)		Strontium-90		Cesium-137	
	First quarter	May	First quarter	May	First quarter	May		First quarter	May	First quarter	May	First quarter	May
Albuquerque, N. Mex.	1.05	1.00	5	4	<5	<5	Memphis, Tenn.	1.30	1.28	8	12	<5	<5
Atlanta, Ga.	1.21	1.22	7	13	5	15	Milwaukee, Wis.	1.23	1.15	5	5	<5	20
Austin, Tex.	1.26	1.22	2	4	<5	5	Minneapolis, Minn.	1.00	1.01	7	5	<5	<5
Baltimore, Md.	1.28	1.18	6	7	5	10	New Orleans, La.	1.31	1.31	8	15	10	20
Boston, Mass.	1.27	1.26	8	11	10	30	New York, N. Y.	[a] 1.18	1.25	[a] 7	10	[a] 5	30
Buffalo, N. Y.	[a] 1.18	1.19	[a] 6	10	[a] <5	20	Norfolk, Va.	[a] 1.20	1.25	[a] 7	10	[a] <5	15
Burlington, Vt.	1.23	1.30	9	9	5	20	Oklahoma City, Okla.	1.29	1.21	5	8	<5	<5
Charleston, S. C.	1.35	1.27	8	14	5	20	Omaha, Nebr.	1.05	1.02	7	8	5	5
Charleston, W. Va.	1.21	1.16	5	10	<5	25	Palmer, Alaska	1.08	1.00	6	8	<5	<5
Charlotte, N. C.	1.28	1.28	9	13	<5	15	Philadelphia, Pa.	1.27	1.16	7	8	<5	10
Chattanooga, Tenn.	1.33	1.34	8	10	<5	10	Phoenix, Ariz.	1.09	0.98	2	5	<5	<5
Chicago, Ill.	[a] 1.16	1.18	[a] 6	6	[a] <5	15	Pittsburgh, Pa.	1.24	1.22	9	12	<5	30
Cincinnati, Ohio.	1.24	1.21	7	10	<5	15	Portland, Me.	[a] 1.20	1.28	[a] 10	9	[a] 10	40
Cleveland, Ohio.	1.21	1.20	6	9	<5	15	Portland, Oreg.	1.11	1.03	8	11	10	15
Dallas, Tex.	1.29	1.24	5	9	<5	<5	Providence, R. I.	1.26	1.25	9	10	10	35
Denver, Colo.	1.03	1.04	6	5	5	<5	Sacramento, Calif.	1.12	0.99	3	4	<5	<5
Des Moines, Iowa.	1.07	1.00	7	6	<5	<5	Salt Lake City, Utah	1.05	1.00	4	8	5	<5
Detroit, Mich.	1.19	1.17	6	10	<5	15	San Francisco, Calif.	1.05	1.02	3	5	<5	<5
Grand Rapids, Mich.	1.24	1.28	7	7	<5	15	San Juan, P. R.	1.15	1.24	3	5	<5	<5
Hartford, Conn.	1.19	1.16	7	8	10	25	Seattle, Wash.	1.09	1.04	7	9	10	15
Helena, Mont.	1.04	0.97	4	6	<5	<5	Spokane, Wash.	1.12	1.01	7	9	5	10
Honolulu, Hawaii.	1.05	0.90	4	6	<5	<5	St. Louis, Mo.	1.01	1.00	7	7	10	10
Idaho Falls, Idaho.	1.05	1.01	5	7	<5	<5	Syracuse, N. Y.	1.22	1.23	6	8	<5	20
Indianapolis, Ind.	1.26	1.21	7	8	<5	15	Tampa, Fla.	1.26	1.22	5	4	35	110
Jackson, Miss.	1.37	1.34	10	14	<5	20	Trenton, N. J.	1.24	1.16	7	8	<5	<5
Kansas City, Mo.	1.05	0.90	7	11	<5	5	Washington, D. C.	1.23	1.19	6	8	<5	30
Laramie, Wyo.	1.06	1.02	5	4	<5	5	Wichita, Kans.	1.05	0.98	5	7	<5	10
Las Vegas, Nev.	1.03	1.01	3	2	<5	<5	Wilmington, Del.	1.22	1.22	7	12	<5	5
Little Rock, Ark.	1.27	1.18	13	22	5	30	Average	1.18	1.15	6	9	<5	15
Louisville, Ky.	1.21	1.22	7	14	<5	15							
Manchester, N. H.	1.21	1.28	8	12	15	55							

[a] Average based on two months samples.

SAMPLING PROGRAMS FOR RADIOACTIVITY IN MILK

The following article is one of a number of discussions concerned with concentrations of radionuclides in milk. This article summarizes data on strontium-90 concentrations in U.S. processed milk for the second quarter of 1960 through the first quarter of 1961. These data were compiled as part of the Public Health Service's Processed Milk Monitoring Program which is designed to document levels of specific radionuclides in milk consumed by the general population. The presentation and data were compiled by Messrs. Roscoe H. Goeke and Andreas P. Zizos of the Data Collation and Analysis Unit, Division of Radiological Health, Public Health Service.

The authors wish to express their appreciation to the Special Projects Branch, Division of Radiological Health, and to the Milk and Food Program, Division of Environmental Engineering and Food Protection, for supplying the basic information.

Strontium-90 Concentrations In U.S. Processed Milk, Second Quarter 1960—First Quarter 1961

Milk Monitoring Program, Division of Radiological Health

Introduction

The Public Health Service Processed Milk Monitoring Program is designed to document levels of specific radionuclides in milk consumed by the general population. Approximately 60 processed milk area sampling stations have been established in cooperation with State and local health and milk sanitation agencies. This program began its operations in March 1960 in order to provide surveillance activities on a continuing basis. The following presentation is a statistical summary of strontium-90 concentrations in processed milk from April 1960 through March 1961 (only a limited number of samples were collected prior to April 1960).

In addition to strontium-90, analyses are conducted for stable calcium, cesium-137, strontium-89, barium-140 and iodine-131. The latter two radioisotopes have been below their minimum detection limits (10 μμc/liter). Strontium-89, with the exception of a small number of samples in March and April 1960, has also been below its minimum detection limit (5 μμc/liter). Cesium-137, strontium-90 and stable calcium concentrations were tabulated in *Radiological Health Data,* Volume II, Number 8. The minimum detectable concentration for strontium-90 is 1 μμc/liter, and its values are reported to the nearest whole number.

Milk is sampled throughout the United States by obtaining samples of pasteurized and homogenized milk at the processing plant. Procedures were developed to provide a sample of one day's sales per month in a community which would be as representative of the total supply as could be achieved under practical conditions. Each sample is a composite of plants supplying not less than 90 percent of a city's milk supply. The contribution from each plant to the total sample is approximately proportional to the volume of milk sold.

Once a month, one sample from each city is sent to either of the Public Health Service's Southwestern or Southeastern Radiological Health Laboratories located in Las Vegas, Nevada, and Montgomery, Alabama, respectively. The latter processes samples from 30 states generally east of the Mississippi, and the former, from the western states. Figure 2 illustrates the geographic distribution of the cities where processed milk is sampled, and table 1 shows their respective coordinates and elevations.

TABLE 1.—COORDINATES AND ELEVATIONS, PROCESSED MILK AREA SAMPLING STATIONS

Area	Latitude	Longitude	Ground elevation (feet)	Area	Latitude	Longitude	Ground elevation (feet)
Albuquerque, N. Mex	35° 03′ N	106° 37′ W	5310	Manchester, N. H	43° 00′ N	71° 28′ W	170
Atlanta, Ga	33° 39′ N	84° 25′ W	975	Memphis, Tenn	35° 03′ N	89° 59′ W	263
Austin, Tex	30° 18′ N	97° 42′ W	615	Milwaukee, Wis	42° 57′ N	87° 54′ W	672
Baltimore, Md	39° 17′ N	76° 37′ W	14	Minneapolis, Minn	44° 53′ N	93° 13′ W	830
Boston, Mass	42° 22′ N	71° 01′ W	15	New Orleans, La	29° 57′ N	90° 04′ W	9
Buffalo, N. Y	42° 56′ N	75° 44′ W	693	New York, N. Y	40° 47′ N	73° 58′ W	132
Burlington, Vt	44° 28′ N	73° 09′ W	331	Norfolk, Va	36° 53′ N	76° 12′ W	26
Charleston, S. C	32° 54′ N	80° 02′ W	41	Oklahoma City, Okla	35° 24′ N	97° 36′ W	1280
Charleston, W. Va	38° 22′ N	81° 36′ W	950	Omaha, Nebr	41° 18′ N	95° 54′ W	978
Charlotte, N. C	35° 13′ N	80° 56′ W	725	Palmer, Alaska	61° 36′ N	149° 05′ W	198
Chattanooga, Tenn	35° 02′ N	85° 12′ W	670	Philadelphia, Pa	39° 53′ N	75° 15′ W	7
Chicago, Ill	41° 47′ N	87° 45′ W	610	Phoenix, Ariz	33° 26′ N	112° 01′ W	1109
Cincinnati, Ohio	39° 09′ N	84° 31′ W	761	Pittsburgh, Pa	40° 30′ N	80° 13′ W	1151
Cleveland, Ohio	41° 24′ N	81° 51′ W	787	Portland, Maine	43° 39′ N	70° 19′ W	61
Dallas, Tex	32° 51′ N	96° 51′ W	476	Portland, Oreg	45° 32′ N	122° 40′ W	30
Denver, Colo	39° 46′ N	104° 53′ W	5292	Providence, R. I	41° 44′ N	71° 26′ W	55
Des Moines, Iowa	41° 32′ N	93° 39′ W	948	Sacramento, Calif	38° 35′ N	121° 29′ W	23
Detroit, Mich	42° 24′ N	83° 00′ W	619	Salt Lake City, Utah	40° 46′ N	111° 58′ W	4220
Grand Rapids, Mich	42° 54′ N	85° 40′ W	681	San Francisco, Calif	37° 47′ N	122° 25′ W	52
Hartford, Conn	41° 56′ N	72° 41′ W	169	San Juan, P. R	18° 28′ N	66° 07′ W	47
Helena, Mont	46° 36′ N	112° 00′ W	3893	Seattle, Wash	47° 36′ N	122° 20′ W	14
Honolulu, Hawaii	21° 19′ N	157° 52′ W	12	Spokane, Wash	47° 37′ N	117° 31′ W	2357
Idaho Falls, Idaho	43° 50′ N	112° 41′ W	4790	St. George, Utah	37° 06′ N	113° 34′ W	2700
Indianapolis, Ind	39° 44′ N	86° 16′ W	793	St. Louis, Mo	38° 45′ N	90° 23′ W	560
Jackson, Miss	32° 20′ N	90° 13′ W	305	Syracuse, N. Y	43° 07′ N	96° 07′ W	424
Kansas City, Mo	39° 07′ N	94° 35′ W	741	Tampa, Fla	27° 48′ N	82° 32′ W	19
Laramie, Wyo	41° 18′ N	105° 34′ W	7236	Trenton, N. J	40° 14′ N	74° 44′ W	56
Las Vegas, Nev	36° 05′ N	115° 10′ W	2162	Washington, D. C	38° 55′ N	77° 00′ W	14
Little Rock, Ark	34° 44′ N	92° 14′ W	257	Wichita, Kans	37° 39′ N	97° 25′ W	1321
Louisville, Ky	38° 11′ N	85° 44′ W	474	Wilmington, Del	39° 40′ N	75° 36′ W	78

TABLE 2.—SUMMARY OF RESULTS, PROCESSED MILK AREA SAMPLING STATIONS, STRONTIUM-90 DETERMINATIONS[a]

(Average concentrations in μμc/liter)

Area	1960				1961	Area	1960				1961
	First quarter	Second quarter	Third quarter	Fourth quarter	First quarter		First quarter	Second quarter	Third quarter	Fourth quarter	First quarter
Albuquerque, N. Mex.	[b] 3	5	4	4	5	Manchester, N. H.		13	11	9	8
Atlanta, Ga.			[c] 11	9	7	Memphis, Tenn.			[b] 14	9	8
Austin, Tex.		[b] 2	2	[c] 2	2	Milwaukee, Wis.			6	6	5
Baltimore, Md.			[c] 7	8	6	Minneapolis, Minn.			[c] 9	8	7
Boston, Mass.		[b] 16	12	10	8	New Orleans, La.			16	11	8
Buffalo, N. Y.		6	7	6	[c] 6	New York, N. Y.		[b] 11	9	8	[c] 7
Burlington, Vt.		10	9	7	9	Norfolk, Va.			9	9	[c] 7
Charleston, S. C.			[c] 10	11	8	Oklahoma City, Okla.			8	7	5
Charleston, W. Va.		9	10	8	5	Omaha, Neb.			[c] 8	6	7
Charlotte, N. C.		[b] 14	12	11	9	Palmer, Alaska	[b] 5	8	7	7	6
Chattanooga, Tenn.			[b] 11	10	8	Philadelphia, Pa.		10	9	6	7
Chicago, Ill.			7	5	[c] 6	Phoenix, Ariz.			4	4	2
Cincinnati, Ohio			9	7	7	Pittsburgh, Pa.		15	11	11	9
Cleveland, Ohio			8	7	6	Portland, Maine		[b] 15	11	9	[c] 10
Dallas, Tex.		[b] 8	6	6	5	Portland, Oreg.		11	10	9	8
Denver, Colo.	[b] 8	8	5	7	6	Providence, R. I.		[b] 18	11	9	9
Des Moines, Iowa		[b] 8	7	[c] 8	7	Sacramento, Calif.			[c] 5	5	3
Detroit, Mich.			7	7	6	Salt Lake City, Utah	[b] 8	7	4	5	4
Grand Rapids, Mich.			8	7	7	San Francisco, Calif.		[b] 8	3	4	3
Hartford, Conn.		9	8	9	7	San Juan, P. R.			4	4	3
Helena, Mont.		[b] 9	6	6	4	Seattle, Wash.		9	8	6	7
Honolulu, Hawaii		3	6	4	4	Spokane, Wash.		10	6	6	7
Idaho Falls, Idaho	[b] 4	7	5	5	5	St. Louis, Mo.			[c] 7	8	7
Indianapolis, Ind.			6	6	7	Syracuse, N. Y.		7	7	7	6
Jackson, Miss.			[c] 12	11	10	Tampa, Fla.			5	6	5
Kansas City, Mo.		8	7	8	7	Trenton, N. J.		[b] 10	7	8	7
Laramie, Wyo.		6	5	5	5	Washington, D. C.			8	8	6
Las Vegas, Nev.	[b] 3	3	2	3	3	Wichita, Kans.		7	6	5	5
Little Rock, Ark.			[c] 13	[c] 13	13	Wilmington, Del.		[b] 10	8	8	7
Louisville, Ky.		7	10	9	7						

[a] Abstracted from *Radiological Health Data*, Volume II, Number 8.
[b] Average based on one month.
[c] Average based on two months.

Strontium-90 Concentrations in U.S. Milk; April 1960 Through March 1961

Table 2 presents the concentrations of strontium-90 in processed milk tabulated by quarters for each station. In all cases, the data were summarized as follows: In each calendar quarter (except for insufficient data during the first quarter of 1960), a mean was calculated for each station. The network and region means, standard deviations, and relative frequencies were calculated by weighing each station average by the number of samples. Histograms showing the distribution of strontium-90 concentrations in processed milk (μμc/liter) were then plotted. These calculations allow for comparisons of the data over relatively long periods of time which approximately correspond to the seasons of the year. The process of calculating quarterly network means and standard deviations from quarterly station averages would tend to make the data normally distributed in accordance with the "Central Limit Theorem." This last point may, or may not, be considered a disadvantage since it allows comparisons of the same type of distributions from one period of time to the next. In this manner, at least relative difference can be noted by simple statistical comparisons. Since there are no models which substantially justify the hypothesis that strontium-90 in processed milk follow some other type of distribution(s),

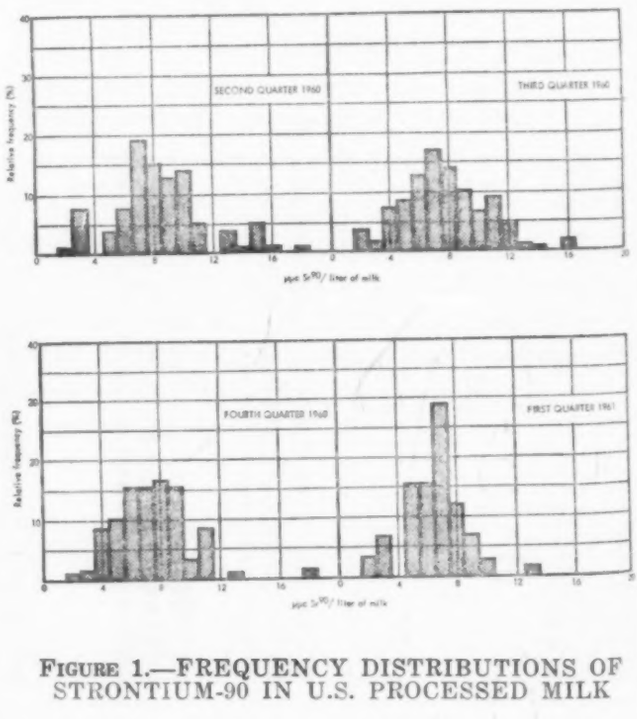


FIGURE 1.—FREQUENCY DISTRIBUTIONS OF STRONTIUM-90 IN U.S. PROCESSED MILK

TABLE 3.—TABULATION OF PERTINENT STATISTICS, STRONTIUM-90 IN U. S. PROCESSED MILK

Period	Number of stations	Number of samples	Mean ($\mu\mu$c/liter)	Standard deviation ($\mu\mu$c/liter)
Second quarter 1960	34	78	8	3
Third quarter 1960	59	164	8	3
Fourth quarter 1960	59	174	7	3
First quarter 1961	59	172	6	2

the method used here does not seem unreasonable. Table 3 presents the important statistics for each quarter. Figure 1 illustrates the distribution of strontium-90 concentrations in processed milk for the second quarter of 1960 through the first quarter of 1961.

A statistical comparison of these data by the use of a "t-test" at the 5 percent significance level reveals the relationships shown below. These relationships, based on the means, variances, significance level, and the number of samples, remain the same whether one assumes that the respective variances are equal or not ($_2\mu_{60}$ denotes the mean for the second quarter of 1960, . . .).

$$
\begin{aligned}
2 \quad & \mu_{60} = 3 \quad \mu_{60} \\
2 \quad & \mu_{60} > 4 \quad \mu_{60} \\
2 \quad & \mu_{60} > 1 \quad \mu_{61} \\
3 \quad & \mu_{60} = 4 \quad \mu_{60} \\
3 \quad & \mu_{60} > 1 \quad \mu_{61} \\
4 \quad & \mu_{60} > 1 \quad \mu_{61}
\end{aligned}
$$

FIGURE 2.—REGIONS OF THE UNITED STATES WITH PROCESSED MILK AREA SAMPLING STATIONS

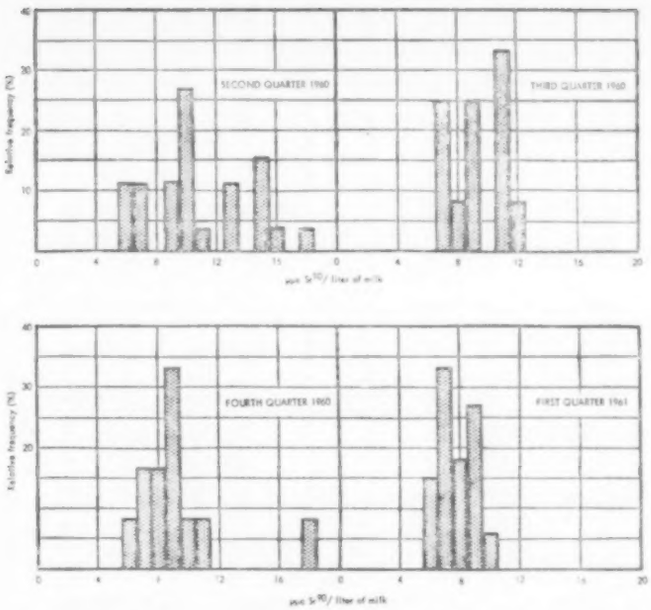


FIGURE 3.—NORTHEAST REGION—FREQUENCY DISTRIBUTIONS OF STRONTIUM-90 IN PROCESSED MILK

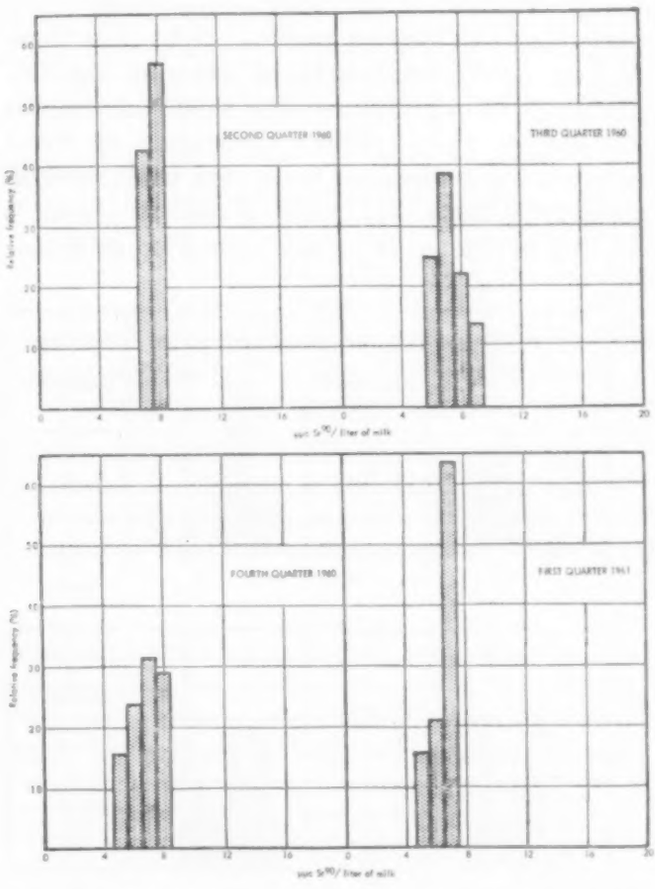
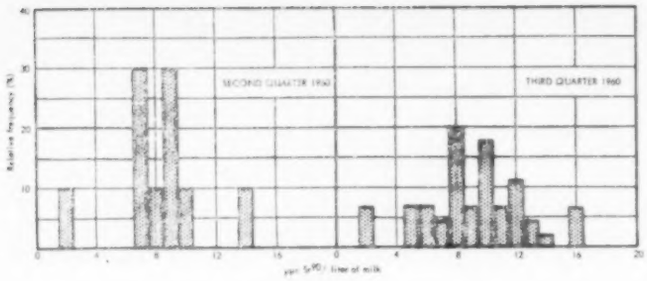


FIGURE 4.—NORTH CENTRAL REGION—FREQUENCY DISTRIBUTIONS OF STRONTIUM-90 IN PROCESSED MILK



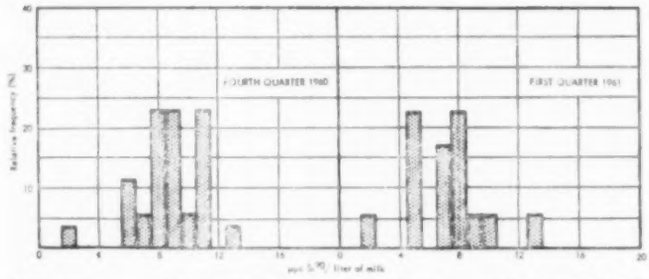


FIGURE 5.—SOUTHERN REGION — FREQUENCY DISTRIBUTIONS OF STRONTIUM-90 IN PROCESSED MILK

Regional Characteristics of Strontium-90 in U.S. Milk

Figure 2 shows the four major geographic regions of the United States. Note that these regions correspond to those used by the Department of Agriculture for their tabulations of average "per person" quantities of foods consumed per week, as presented in *Radiological Health Data,* Volume I, Numbers 6 and 7. By this grouping, the stations located at Honolulu, Hawaii; Palmer, Alaska; and San Juan, Puerto Rico, have been excluded.

Figures 3 through 6 illustrate the relative distributions of strontium-90 in processed milk in each of the four regions of the United States. For each region, four histograms are presented, one for each of the four quarters concerned within this presentation. The important statistics are included in table 4. Means, standard deviations, and relative frequencies were computed in the manner described in the previous section.

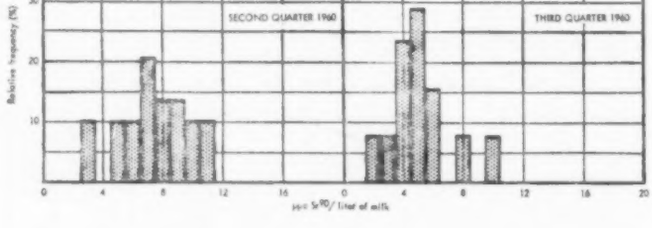
TABLE 4.—TABULATION OF PERTINENT STATISTICS FOR EACH REGION, STRONTIUM-90 IN U. S. PROCESSED MILK

Region	Period	No. of stations	No. of samples	Mean (μμc/liter)	Standard deviation (μμc/liter)
Northeast	2nd quarter 1960	12	26	11	3
	3rd quarter 1960	12	36	9	2
	4th quarter 1960	12	36	9	3
	1st quarter 1961	12	33	8	1
North Central	2nd quarter 1960	3	7	8	1
	3rd quarter 1960	13	36	7	1
	4th quarter 1960	13	38	7	1
	1st quarter 1961	13	38	6	1
South	2nd quarter 1960	6	10	8	3
	3rd quarter 1960	18	45	9	3
	4th quarter 1960	18	52	9	2
	1st quarter 1961	18	53	7	2
West	2nd quarter 1960	11	29	7	2
	3rd quarter 1960	13	38	5	2
	4th quarter 1960	13	39	5	2
	1st quarter 1961	13	39	5	2

A statistical comparison of the data, by the use of a "t-test" at the 5 percent significance level, reveals the relationships shown below for each region during each of the four quarters considered in this presentation. These relationships remain the same whether one assumes equal or unequal variance (μ_{NE} denotes the mean for the Northeast, . . .).

For each quarter the relationships are:

Second Quarter 1960	Third Quarter 1960
$\mu_{NE} > \mu_{NC}$	$\mu_{NE} > \mu_{NC}$
$\mu_{NE} > \mu_{S}$	$\mu_{NE} = \mu_{S}$
$\mu_{NE} > \mu_{W}$	$\mu_{NE} > \mu_{W}$
$\mu_{NC} = \mu_{S}$	$\mu_{NC} < \mu_{S}$
$\mu_{NC} = \mu_{W}$	$\mu_{NC} = \mu_{W}$
$\mu_{S} = \mu_{W}$	$\mu_{S} > \mu_{W}$



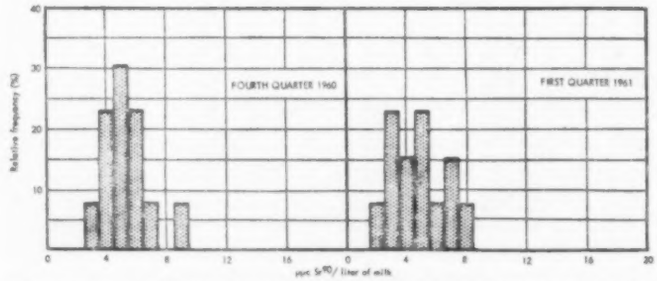


FIGURE 6.—WESTERN REGION FREQUENCY DISTRIBUTIONS OF STRONTIUM 90 IN PROCESSED MILK

Fourth Quarter 1960	First Quarter 1961
$\mu_{NE} > \mu_{NC}$	$\mu_{NE} > \mu_{NC}$
$\mu_{NE} = \mu_{S}$	$\mu_{NE} > \mu_{S}$
$\mu_{NE} > \mu_{W}$	$\mu_{NE} > \mu_{W}$
$\mu_{NC} < \mu_{S}$	$\mu_{NC} < \mu_{S}$
$\mu_{NC} > \mu_{W}$	$\mu_{NC} > \mu_{W}$
$\mu_{S} > \mu_{W}$	$\mu_{S} > \mu_{W}$

Intra-region comparisons for each of the four quarters, using the statistical tests described in the preceding paragraph, show the relationships listed below. Similarly, these relationships are the same whether one assumes equal, or unequal variance ($2\mu 60$ denotes the mean for the second quarter of 1960.)

Northeast	North Central	South	West
$2\mu_{60} > 3\mu_{60}$	$2\mu_{60} \geq 3\mu_{60}$	$2\mu_{60} = 3\mu_{60}$	$2\mu_{60} > 3\mu_{60}$
$2\mu_{60} > 4\mu_{60}$	$2\mu_{60} \geq 4\mu_{60}$	$2\mu_{60} = 4\mu_{60}$	$2\mu_{60} > 4\mu_{60}$
$2\mu_{60} > 1\mu_{61}$	$2\mu_{60} > 1\mu_{61}$	$2\mu_{60} = 1\mu_{61}$	$2\mu_{60} > 1\mu_{61}$
$3\mu_{60} = 4\mu_{60}$	$3\mu_{60} = 4\mu_{60}$	$3\mu_{60} = 4\mu_{60}$	$3\mu_{60} = 4\mu_{60}$
$3\mu_{60} > 1\mu_{61}$	$3\mu_{60} > 1\mu_{61}$	$3\mu_{60} > 1\mu_{61}$	$3\mu_{60} = 1\mu_{61}$
$4\mu_{60} = 1\mu_{61}$	$4\mu_{60} > 1\mu_{61}$	$4\mu_{60} > 1\mu_{61}$	$4\mu_{60} = 1\mu_{61}$

The statistical relationships shown throughout the text constitute the conclusions of the authors. In no case was there ever a difference of more than 3$\mu\mu$c Sr^{90}/liter of milk between any two means or standard deviations. Special mention is made of this fact so that the reader is not mislead into assuming that large variations occur from one time period to the next, or from region to region.

REFERENCES

(1) *Radiological Health Data*, Volume I, Numbers 1–9 and Volume II, Numbers 1–10.

Strontium-90 In Bovine Milk From Minnesota

Division of Environmental Sanitation
Minnesota Department of Health

The Minnesota State Department of Health, Division of Environmental Sanitation, initiated a small bovine milk surveillance network in September 1958. Two-ounce samples, collected daily at each of the network stations, are composited and analyzed monthly. Collection is made at the bottling machines so that the sample is randomly representative of the milk produced in that milkshed.

Results for the period January-April 1960 were published in *Radiological Health Data*, Volume I, Number 9 and May-November 1960 in Volume II, Number 6. The most recently reported data from this network are presented below.

TABLE 1.—STRONTIUM-90 IN BOVINE MILK FROM MINNESOTA, DECEMBER 1960–MAY 1961

[Concentrations in $\mu\mu$c/liter]

Month	Brainerd	Duluth	Minneapolis	Thief River Falls	Worthington	Rochester
December 1960	15.3	14.1	5.1	----	5.3	6.0
1960 Average	16.0	13.3	7.1	9.3	6.9	6.8
January 1961	14.3	14.3	9.2	7.0	5.5	6.3
February 1961	----	12.6	6.7	6.7	6.4	6.4
March 1961	11.4	13.4	7.1	----	6.4	7.3
April 1961	10.3	14.4	6.6	5.8	6.3	5.1
May 1961	16.7	15.7	7.0	----	7.7	----

SECTION IV. — WATER

National Water Quality Network

Division of Water Supply and Pollution Control, Public Health Service

The National Water Quality Network operates under the provision of Section 4(c) of the Federal Water Pollution Control Act, which states ". . . The Secretary shall . . . collect and disseminate basic data . . . (relating) to water pollution and the prevention and control thereof."

This Network, operated in cooperation with State and local agencies, and industrial organizations commenced operations in October 1957. At present, there are 86 sampling stations located on major waterways used for public water supply, propagation of fish and wildlife, recreational purposes, and for agricultural, industrial, and other uses. Some of these stations are on interstate, coastal, and International Boundary waters, and waters on which activities of the Federal Government may have an impact. Ultimately, a total of approximately 300 stations will be in operation. Radioactivity is not yet being reported for a few of the more recently established stations.

Samples of water are examined for chemical, physical, and biological quality insofar as these relate to pollution. Samples for some determinations are taken weekly, others monthly, and for some, continuous composite samples of 10 to 15 days are obtained.

Gross alpha and beta measurements are made on both suspended and dissolved solids in raw surface water samples. The levels of radioactivity associated with dissolved solids provide a rough measure of the levels which may be found in a treated water, where such water treatment removes substantially all of the suspended matter. Naturally-occurring radioactive substances in the environment are the source of essentially all of the alpha activity. The contamination of the environment from man-made sources is the major contributor to the beta activity. During the cessation of weapons testing, the beta activity in most raw waters generally approached a level attributable solely to natural sources. Natural beta activity can be two or three times the natural alpha activity based on the presence of the same nuclides. Some exceptions to this are seen, notably in the data for the Columbia, Tennessee and Animas Rivers.

For the first two years of the network operations, beta determinations were made on weekly samples. Alpha determinations were reported generally on composites of more than one weekly sample.

Beginning January 1, 1960 the frequency of *beta* determinations has varied depending on the status of each particular station. For the first operating year of each new station, analyses have been conducted weekly. Weekly analyses are continued indefinitely from all

stations which may be affected by waste discharges from nuclear installations. Semimonthly determinations (on composites of 2 or 3 weekly samples) are conducted for stations which still show some beta activity above background. Monthly determinations (on composites of all samples received from a station during the month) are conducted on samples from streams where beta activity is at background levels.

Beginning January 1, 1960, the frequency of *alpha* determinations has also been changed. For the first operating year of each new station, analyses have been done weekly. Semimonthly determinations are conducted at some collecting points on the Animas and Colorado Rivers by compositing 2 or 3 weekly samples. The remainder of the stations have determinations made quarterly on composites of all samples taken during that quarter. Schedules of determinations are so arranged that each river basin has one gross alpha determination each month.

All data reported in table 1 represent the average of all information available for the month indicated. Reported strontium-90 data are the results of determinations on composite samples for a three-month period ending in the month shown.

Additional information and data may be obtained from the following sources:

National Water Quality Network Annual Compilation of Data, PHS Publication. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price $1.50.

"Report on National Water Quality Control Network," submitted by Dr. F. J. Weber, Chief, Division of Radiological Health, PHS, at the Joint Committee on Atomic Energy Hearings on Fallout from Nuclear Weapons Tests, Vol. 1, May 1959, pages 167–169.

Setter, L. R., Regnier, J. E., and Diephaus, A., "Radioactivity of Surface Waters in the United States," Jour. AWWA *51,* 1377 (1959).

Straub, C. P., Setter, L. R., Goldin, S., and Hallbach, P. F., "Strontium-90 in Surface Waters," Jour. AWWA *52,* 756 (1960).

Setter, L. R., and Baker, S. L., "Radioactivity of Surface Waters in the United States," *Radiological Health Data,* Volume I, No. 7 (1960).

FIGURE 1.—NATIONAL WATER QUALITY NETWORK SAMPLING STATIONS

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS

[Concentrations in $\mu\mu c$/liter]

Station	Quarter ending March 31, 1961	April 1961					
		Beta activity			Alpha activity		
	Strontium-90	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River: Pittsburgh, Pa	[a] —	0	0	0	<1	1	<1
Animas River: Cedar Hill, N. Mex	—	33	5	38	17	10	27
Apalachicola River: Chattahoochie, Fla	—	0	0	0	0	0	0
Arkansas River:							
Coolidge, Kans	—	0	3	3	8	80	88
Ponca City, Okla	—	0	0	0	10	2	12
Pendleton Ferry, Ark	—	0	0	0	1	0	1
Chattahoochie River:							
Atlanta, Ga	—	0	2	2	0	0	0
Columbus, Ga	0.3	0	0	0	1	<1	1
Colorado River:							
Loma, Colo	0.4	0	0	0	4	9	13
Page, Ariz	—	109	9	118	53	10	63
Boulder City, Nev	—	1	0	1	0	6	6
Parker Dam, Ariz-Calif	—	0	16	16	0	10	10
Yuma, Ariz	1.2	0	<1	<1	0	5	5
Columbia River:							
Wenatchee, Wash	0.7	0	5	5	0	1	1
Pasco, Wash	1.0	96	420	516	—	—	—
Bonneville Dam, Oreg	—	44	183	227	0	0	0
Clatskanie, Oreg	—	28	93	121	—	—	—
McNary Dam, Oreg	—	56	205	261	0	0	0
Delaware River:							
Martins Creek, Pa	—	0	0	0	1	0	1
Philadelphia, Pa	0.6	1	0	1	1	0	1
Great Lakes:							
Buffalo, N. Y	0.6	0	0	0	0	1	1
Port Huron, Mich	—	0	1	1	0	0	0
Detroit, Mich	—	0	0	0	0	1	1
Gary, Ind	—	0	0	0	0	0	0
Duluth, Minn	0.4	0	0	0	0	0	0
Milwaukee, Wis	—	3	4	7	0	0	0
Sault St. Marie, Mich	—	0	1	1	0	0	0
Hudson River: Poughkeepsie, N. Y	0.4	0	0	0	1	0	1
Illinois River: Peoria, Ill	—	0	0	0	0	2	2
Kanawha River: Winfield Dam, W. Va	0.2	0	0	0	0	0	0
Klamath River: Copco, Oreg	—	0	1	1	0	0	0
Little Miami River: Cincinnati, Ohio	1.1	0	0	0	1	1	2
Mississippi River:							
Minneapolis, Minn	—	0	1	1	0	2	2
Dubuque, Iowa	—	0	0	0	2	0	2
Burlington, Iowa	[b]	0	0	0	1	0	1
E. St. Louis, Ill	—	5	3	8	8	2	10
Cape Girardeau, Mo	0.7	34	0	34	19	0	19
West Memphis, Ark	—	0	0	0	1	1	2
Delta, La	[b]	2	0	2	3	1	4
New Orleans, La	—	22	0	22	13	0	13
Missouri River:							
Williston, N. Dak	0.8	0	0	0	2	5	7
Bismarck, N. Dak	—	0	0	0	0	0	0
Yankton, S. Dak	—	0	0	0	1	3	4
Omaha, Nebr	—	17	3	20	6	5	11
St. Joseph, Mo	—	19	8	27	8	3	11
Kansas City, Kans	1.4	0	0	0	9	5	14
St. Louis, Mo	1.1	26	2	28	33	2	35
Ohio River:							
East Liverpool, Ohio	—	0	0	0	1	0	1
Huntington, W. Va	—	0	0	0	1	1	2
Cincinnati, Ohio	0.3	2	0	2	2	0	2
Evansville, Ind	—	0	0	0	2	0	2
Cairo, Ill	—	6	1	7	1	0	1
Potomac River:							
Hagerstown, Md	—	0	7	7	0	0	0
Great Falls, Md	1.3	0	0	0	1	0	1
Red River, North: Grand Forks, N D	—	1	2	3	<1	1	1
Red River, South:							
Index, Ark	0.4	0	0	0	9	0	9
Alexandria, La	—	56	0	56	28	0	28
Denison, Tex	—	0	0	0	0	2	2
Rio Grande River:							
Alamosa, Colo	—	0	0	0	0	0	0
El Paso, Tex	0.4	0	9	9	0	4	4
Laredo, Tex	0.4	0	0	0	1	6	7
Brownsville, Tex	—	0	0	0	5	4	9
Sabine River: Ruliff, Tex	—	<1	4	4	1	<1	1
St. Lawrence River: Massena, N. Y	—	0	0	0	0	0	0
Schuylkill River: Philadelphia, Pa	—	0	0	0	1	0	1
Savannah River:							
Port Wentworth, Ga	0.4	<1	3	3	1	0	1
North Augusta, S. C	—	0	0	0	0	0	0
Snake River:							
Wawawai, Wash	—	0	3	3	0	1	1
Weiser, Idaho	—	0	0	0	0	6	6
Susquehanna River:							
Sayre, Pa	—	0	0	0	1	0	1
Conowingo, Md	—	<1	2	2	0	0	0
Tennessee River:							
Chattanooga, Tenn	0.8	1	34	35	—	—	—
Bridgeport, Ala	1.5	0	31	31	0	0	0
Yakima River: Richland, Wash	—	0	0	0	0	0	0
Yellowstone River: Sidney, Mont	—	0	0	0	1	3	4

[a] Dash denotes no sample received or no determinations made.
[b] Insufficient sample for Sr^{90} analysis.

SECTION V. — OTHER DATA

External Gamma Activity

Radiation Surveillance Network, Public Health Service

Portable survey instruments are available at stations of the Radiation Surveillance Network for recording levels of external gamma radiation. Measurements are made daily approximately three feet above the ground. These readings are not precise but are sufficiently accurate to illustrate any significant variations above background. The differences among the values shown in the following table are within the variance anticipated due to differences in normal background and in instrument response characteristics.

TABLE 1.—EXTERNAL GAMMA ACTIVITY, MAY 1961

Station location	Average (mr/hr)	Station location	Average (mr/hr)
Anchorage, Alaska	0.01	Minneapolis, Minn	0.01
Fairbanks, Alaska	[a]	Pascagoula, Miss	[a]
Juneau, Alaska	0.01	Jefferson City, Mo	0.01
Phoenix, Ariz	0.02	Helena, Mont	0.03
Little Rock, Ark	0.02	Trenton, N. J	0.02
Berkeley, Calif	0.01	Santa Fe, N. Mex	[a]
Los Angeles, Calif	[a]	Albany, N. Y	0.09
Denver, Colo	0.02	Gastonia, N. C	0.02
Hartford, Conn	0.01	Oklahoma City, Okla	0.02
District of Columbia	0.02	Ponca City, Okla	0.02
Jacksonville, Fla	0.01	Portland, Oreg	0.02
Atlanta, Ga	[a]	Harrisburg, Penn	0.01
Honolulu, Hawaii	0.03	Providence, R. I	0.02
Boise, Idaho	0.01	Columbia, S. C	0.03
Springfield, Ill	0.03	Pierre, S. D	0.02
Indianapolis, Ind	0.01	Austin, Tex	0.01
Iowa City, Iowa	0.01	El Paso, Tex	0.02
Topeka, Kans	0.03	Salt Lake City, Utah	0.02
New Orleans, La	0.01	Richmond, Va	0.01
Baltimore, Md	0.02	Seattle, Wash	0.02
Lawrence, Mass	0.02	Madison, Wis	0.01
Lansing, Mich	0.02	Cheyenne, Wyo	0.02

[a] No data received.

Cesium-137 Levels In Humans

Walter Reed Army Institute of Research, Washington, D.C., and
U.S. Army Medical Research Unit, Landstuhl, Germany

The whole body counting facilities at the Walter Reed Army Institute of Research (WRAIR), Washington, D. C., and the Medical Research Unit, Landstuhl, Germany, have continued their program for measuring the levels of cesium-137 in people. A description of each facility and previous data were summarized in *Radiological Health Data*, Volume II, Number 4; subsequent data appeared in Volume II, Number 7.

This report presents results from Germany for the period March through May 1961, and from Walter Reed for the second quarter of 1961. The Landstuhl data are listed by month in table 1 and the Walter Reed data are listed by geographic area in tables 2 and 3.

TABLE 1.—ASSAYS PERFORMED AT THE U. S. ARMY MEDICAL RESEARCH UNIT, LANDSTUHL, GERMANY

Date	Subjects residing in—	Number of subjects	$\mu\mu c$ Cs^{137}/gm K (average)
March 1961	West Germany	216	37
April 1961	West Germany	85	43
May 1961	West Germany	234	37

TABLE 2.—ASSAYS PERFORMED AT THE WALTER REED ARMY INSTITUTE OF RESEARCH, SECOND QUARTER, 1961

Geographic area	Number of subjects	$\mu\mu c$ Cs^{137}/gm K (average)
Australia	1	36
Caribbean	3	20
Europe	11	49
Far East	3	19
United States	75	32

TABLE 3.—ASSAYS OF INDIVIDUALS RESIDING WITHIN THE UNITED STATES PERFORMED AT WRAIR, SECOND QUARTER, 1961

State	Number of subjects	μc Cs^{137}/gm K (average)
Arkansas	1	29
California	1	10
District of Columbia	7	32
Florida	2	52
Georgia	1	46
Hawaii	1	31
Illinois	3	34
Indiana	2	25
Kentucky	2	39
Louisiana	1	31
Maine	1	23
Maryland	6	46
Massachusetts	2	37
Michigan	1	11
Minnesota	1	57
New Jersey	7	30
New York	12	30
North Carolina	1	27
Ohio	1	31
Pennsylvania	9	31
Rhode Island	1	26
South Carolina	1	27
Tennessee	2	21
Texas	3	19
Virginia	5	25
Wyoming	1	30

TABLE 4.—SUMMARY OF TABLES 1 AND 2—SECOND QUARTER, 1961

Geographic area	Number of subjects	$\mu\mu c$ Cs^{137}/gm K (average)	Percent MPC[1]
Australia	1	36	0.18
Caribbean	3	20	0.10
Europe	11	49	0.25
Far East	3	19	0.10
West Germany	535	[2] 38	0.19
United States	75	32	0.16

[1] *Radiological Health Data*, Volume II, Number 4, pages 193 and 194.
[2] Values represent determinations for March through May 1961.

RADIOLOGICAL HEALTH CONSIDERATIONS AND FINDINGS RELATED TO THE USE OF MEDICAL AND DENTAL X-RADIATION

The following two articles are the second and third in a series of presentations intended to discuss or present information, philosophical considerations, or summaries of data concerning the radiological health aspects of medical and dental X-radiation. These discussions will be related primarily to the factors involved in the ultimate reduction of the somatic and genetic exposure dose delivered to the general population. The first article by Hanson

Blatz, entitled, "Some Reflections on Current Plans to Control Radiation Exposure in the United States," appeared in *Radiological Health Data*, Volume II, Number 8. Mr. Blatz stressed that emphasis should not be placed on controlling exposure from radioisotopes to the exclusion of controlling exposure from machine-produced radiation.

In conducting field surveys of dental X-ray units, it is necessary to interpret and clarify the definition of a "diagnostic type protective tube housing" as recommended by the National Committee on Radiation Protection and Measurements in the National Bureau of Standards Handbook Number 76, February 1961, before a proper and realistic appraisal of the radiation leakage from such a housing can be accomplished. In the first of the two papers presented here, Mr. Edgar F. Seagle,[1] Program Operations Branch, Division of Radiological Health, Public Health Service, discusses practical considerations and a positive approach in accomplishing such an appraisal.

[1] At the present time, Mr. Seagle is assigned by the Public Health Service to the Florida State Department of Public Health.

The author wishes to express his appreciation to George L. Crocker, D.D.S., James W. Miller, D.D.S., and Henry J. L. Rechen, Program Operations Branch, Division of Radiological Health, Public Health Service, for their valuable assistance.

The second of the two papers presented, by Mr. Herbert A. Bevis,[2] Texas State Department of Health, deals with, illustrates, and discusses data derived from a radiological safety survey of 140 dental X-ray units in Texas.[3]

Mr. Bevis expresses his appreciation to Dr. W. A. Buckner, Division of Dental Health and Mr. R. G. Griffin, Jr., Division of Occupational Health, Texas State Department of Health, and to Drs. G. A. Nevitt and J. T. Lovett, Public Health Service, Region VII, Dallas, Texas, for assisting in, and contributing to, the successful completion of this study.

[2] Mr. Bevis was assigned by the Public Health Service to the Texas State Department of Health, as Chief of the Ionizing Radiation Program, Division of Occupational Health, at the time this paper was prepared.

[3] A summary of the author's findings were also presented at the 36th Annual Meeting of the Texas Public Health Association at Fort Worth, Texas, held during March 5–8, 1961.

Measurement of Leakage Radiation From Dental X-Ray Tube Housings

Program Operations Branch
Division of Radiological Health, Public Health Service

Introduction

The purpose of this paper is to provide background material for survey teams who may try to determine compliance with paragraph 1, page 2 of National Bureau of Standards "Handbook, No. 76," entitled "Diagnostic Type Protective Tube Housing." This paragraph states that such a tube housing is an "X-Ray tube housing so constructed that the leakage radiation at a distance of one meter from the target cannot exceed 100 mr in one hour when the tube is operated at any of its specified ratings." The rating of a tube may be specified in terms of "continuous operation" or in terms of individual exposures with a duty cycle. As dental X-ray units are used to make individual exposures, the duty cycle for such exposures must be considered. To understand the above paragraph, one must be familiar with the individual terms included therein:

X-ray Tube Housing: The tenth edition of "Fundamentals of Radiography" (*1*) states that, "most diagrams of the X-ray tube show X-rays as forming a neat triangular pattern as they are produced at the focal spot. This serves a good purpose in emphasizing the action of X-radiation outside the tube. However, the radiation does not behave in that way. Actually, X-rays are like visible light in that they radiate from the source in straight lines in all directions unless they are stopped by an absorber. For that reason, the X-ray tube is enclosed in a metal "housing" that stops most of the X-radiation; only the useful rays are permitted to leave the tube through a window or port. These useful rays are called the "primary beam" (refer to figure 1).

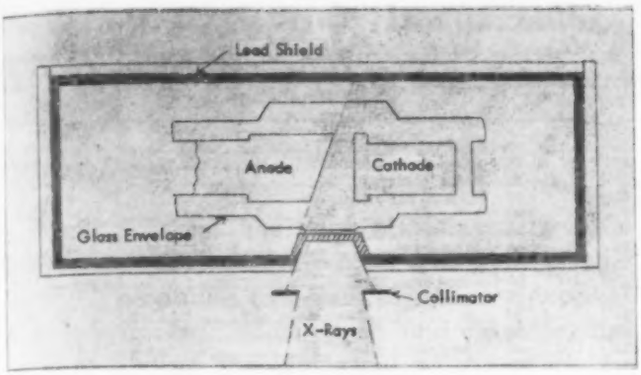


FIGURE 1.—DIAGRAM SHOWING THAT X-RAYS RADIATE IN STRAIGHT LINES IN ALL DIRECTIONS FROM THE SOURCE. THEREFORE, THERE IS NEED FOR THE METAL HOUSING AROUND THE TUBE [Courtesy of X-ray Division, Eastman Kodak Company (*1*).]

Leakage Radiation: According to the National Bureau of Standards Handbook No. 76, leakage radiation is all radiation coming from within the tube housing, *except* the useful beam. The useful beam is that portion of the radiation which passes through the window, aperture, cone, or other collimating device of the tube housing.

1 M: This term is the abbreviation for one meter. Its equivalent length is 3.2808 feet, or 39.4 inches.

Target: Quoting from "Fundamentals of Radiography" (*1*), "The simplest form of X-ray tube is a sealed glass envelope from which the air has been pumped and containing two important parts—the anode and the cathode. The anode is usually formed of copper and extends from the end of the tube to the center. A block of tungsten about one-half inch square is set in the anode face at the center of the tube. This is called the *target*. The small area of the target that the electrons strike is called the focal spot and it is the source of the X-rays."

100 mr in one hour: 100 mr is 100 milliroentgens or 0.1 of a roentgen. The roentgen is the unit of exposure dose of X- or gamma radiation. 100 mr *in* one hour means the total exposure dose at some specified location for one hour.

Specified ratings: The rating of an X-ray tube is the amount of time the tube can be mechanically operated safely during a single exposure. However, this gives no information as to how frequently exposures can be made. To provide this information, a duty cycle must be specified.

Duty Cycle: With regard to X-ray tubes, this term refers to the period of activation per unit time, (e.g., so many seconds in one minute), that a tube can be energized without damage to that tube. In other words, the tube may be energized so many seconds in each minute during the entire working day without exceeding the manufacturers' prescribed safe limits. This duty cycle will vary with the kilovolts peak potential (kvp) and the tube current, expressed in milliamperes (ma).

Significance of Duty Cycle Ratings to X-Ray Survey Teams

In the process of conducting a radiation safety survey of a dental X-ray installation, if one uses a suitable ion chamber type instrument with an energy response known for the quality of the X-rays generated and evaluates the exposure dose rate at 1 meter from the tube target as 100 mr per hour, an erroneous interpretation may be that this is the actual total leakage radiation delivered in that part of one hour. For this to be true, it would be necessary to activate the tube continuously for 1 hour. This is impractical, since no dental diagnostic X-ray tube is activated continuously for this length of time. Therefore, one must consider how long, or for what maximum time, a tube could be activated in 1 hour. Thus, the duty cycle becomes a significant consideration. For example, if the duty cycle should be 4 seconds of activation for each minute of continuous operation, the maximum time a well informed operator would activate the tube would be 4 minutes in 1 hour. Consequently, a true reading of 100 mr/hr, obtained on a unit with a 4 sec./min. duty cycle, would actually be a total of 6.66 mr in 1 hour, based on the length of time the tube could be activated in that hour.

It is evident from the following simple calculation that to obtain a total of 100 mr in 1 hour, from a unit with a 4-second-per-minute duty cycle, the "true" exposure dose measured at one meter would have to be 1500 mr/hr:

$$\frac{100 \text{ mr/hr}}{6.66 \text{ mr total}} = \frac{x}{100 \text{ mr total}}$$

$$6.66\,x = 10{,}000$$

$$x = 1500 \text{ mr/hr}$$

TABLE 1.—DUTY CYCLE RATINGS FOR DENTAL X-RAY UNITS[1]

Company	Model	Current (ma)	Voltage (kvp)	Duty Cycle (Continuous Operation)	Conversion Factor[2]
Ritter	A	10	63	6.5 secs. each min	0.1082
	B	10	50–70	4.5 secs. each min	0.0749
	Dual—X	15	70	4 secs. each min	0.0666
	E (Century)	15	90	3.6 secs. each min	0.060
	F	15	90	do	0.060
G. E	Victor (Old Style)	10	58	Unknown	
	CDX-E	10	65	Unknown	
	70	10	70	3½ secs. at 2 ea. min	0.1165
	90-II	15	90	4 secs. each min	0.0666
XRM	2A	15	70	do	0.0666
	3A	15	70	do	0.0666
	90	15	90	do	0.0666
Weber	6	10	65	6 secs. each min	0.10
	6A	10	65	do	0.10
	6B	10	65	do	0.10
	6R	10	65	do	0.10
	7	10	65	do	0.10
	7A	10	65	do	0.10
	9A	10	65	do	0.10
	11	10	65	do	0.10
	11E	10	65	do	0.10
	Raydex (70)	10	70	4.5 secs. each min	0.0749
	Raydex 12R (90)	15	90	3 secs. each min	0.050
Fischer		10	65	4 secs. each min	0.0666

[1] The information listed in this table has been obtained from personal communications (4–9).
[2] Multiply the "true" exposure dose rate determined at one meter from the tube target by the correction factor to obtain the quantity of leakage radiation in 1 hour.

These relationships show that for a duty cycle of 4 seconds per minute, the total leakage radiation in one hour would be 6.66 percent of the reading shown on the ion chamber. A percentage factor in multiplying the ion chamber reading should be computed for each individual duty cycle. This has been done for the most common dental units. Calculations were based on the assumption that operators of dental X-ray units do adhere to the specified duty cycle. The kvp and ma settings shown for the various makes of dental X-ray units in table 1 are not unreasonably representative of those actually employed.

A good average conservative estimate of the correction factor seems to be 0.1. Therefore, it would not be inappropriate to apply this factor to such other units as the Philips Oralix, Universal, Westinghouse, Meyer, Wappler, Grenz-Ray, and Norelco. This figure may also be used by inspectors as a conversion factor for models listed in table 1 where specific information for a given unit is unknown. For example, the duty cycle and conversion factor for a 15 ma and 90 kvp unit may be given, but if the unit is operated at less than 15 ma and 90 kvp the conversion factor has not been calculated. In all such cases it is recommended that one use 0.1. This figure is a conservative average and allows for a maximum safety factor of approximately 2.0.

Conclusion

The results of this investigation show that the duty cycle must be known, and it must be considered in order to obtain a practical appraisal of the leakage radiation from dental X-ray tube housings as defined in the recommendations stated in Handbook No. 76 (*4*).

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Radiation Hygiene In Dental Offices Of Texas

Division of Occupational Health, Texas State Department of Health

Discussion

Public interest has been stimulated by hazards associated with exposure to ionizing radiation. The public has been constantly exposed to a barrage of information and misinformation concerning the biological effects of radiation. As a result, some people have become so concerned that they are hesitant to submit to X-ray examinations, even when they are recommended by physicians or dentists.

If it could be stated authoritatively that radiation presented no hazard to those individuals exposed, these fears could probably be dispelled. However, most experts agree that all radiation exposure is potentially injurious—not only to the person exposed, but to his decendants as well. The medical and dental use of X-radiation is the greatest source of exposure to the public (*1*). It is the responsibility of these professions to constantly reevaluate their use of radiation equipment and techniques in order to be certain that their exposure of the public, and of assistants and themselves, is kept to an absolute minimum.

TABLE 1.—RESPONSE OF DENTISTS

District	Number of members	Number of survey requests	Percent participation
1	43	23	54
14	64	36	56
15-B	46	36	78
21-A	33	24	73
Total	186	118	63

Studies have been conducted to ascertain the radiation exposure to dental patients, (*2*) and to dental office personnel (*3, 4, 5*). The American Academy of Oral Roentgenology (AAOR) and the National Committee on Radiation Protection and Measurements (NCRP&M) have offered recommendations to reduce these exposures (*6, 7*). Generally speaking, steps taken to reduce exposure to the patient will also reduce exposure to office personnel. The converse is usually true as well.

The Texas State Department of Health, in cooperation with the Texas Dental Association and the Public Health Service, Department of Health, Education, and Welfare, conducted a study to determine the status of radiation protection practices in dental offices of Texas. Component society districts (1, 14, 15-B and 21-A) of the Texas Dental Association were selected as loci for this investigation. It is felt that dental offices in these districts are representative of the State, and data obtained in this study can be considered typical of dental X-ray installations in Texas.

TABLE 2.—CONDITION OF X-RAY EQUIPMENT

Statistic	District				Sum	Percent of total
	1	14	15-B	21-A		
Number of X ray units	31	40	42	27	140	
Initially satisfactory	3	1	4	3	11	8
Inadequate filtration[a]	24	37	33	24	118	84
Excessive beam diameter[b]	16	26	27	18	87	62
Non-radiation effects[c]	4	5	3	0	12	9
Units corrected[d]	24	34	35	24	117	84

[a] The AAOR's recommended value of 2.0 mm total aluminum equivalent filtration was used.

[b] The AAOR's recommended beam diameter of ¾ inches at the tip of the pointer cone was employed.

[c] "Non-radiation defects" include: electrical by-pass timer, inadequate grounding of electrical components, exposed electrical wiring; mechanical instability of X-ray tube head.

[d] The Texas Dental Association provided the lead and aluminum for fabricating the diaphragms and filters. The latter were fabricated by the Texas State Department of Health. The dies were designed by Mr. Bevis.

Summary of Results

Prior to initiating any field surveys in an area, the local dental society was informed of

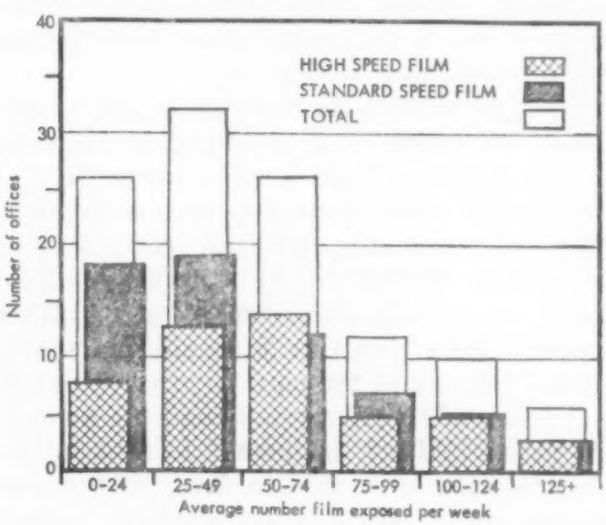

FIGURE 1.—DISTRIBUTION OF THE NUMBER OF X-RAY FILMS EXPOSED WITH FILM SPEED AS THE PARAMETER

the program and their cooperation was solicited. An explanatory letter and a reply post card were sent to each member of the local society. Radiological surveys were made of the offices of only those dentists who specifically requested such services by return of the post card. These cards requested preferred times for office visits, and some basic information about the X-ray units to be surveyed. Tables 1 and 2, and figure 1 present some of the results obtained in this study. The survey team which visited each office consisted of two people.

The response of dentists from the districts selected for study is presented in table 1. It should be noted that invitations were sent to all members of the local societies. This membership includes retired dentists as well as others not actively engaged in the practice of dentistry. Consequently, the composite response of 63 percent is better than it would appear.

A number of those dentists who did not request a survey of their offices may have recently purchased X-ray units. Some are under the impression that all new or reconditioned X-ray equipment automatically meets the recommended standards. Unfortunately, this is not true. Of the 140 X-ray units inspected during the course of this study, only 11 units (less than 8%) met the recommendations of the National Committee on Radiation Protection and Measurements and the American Academy of Oral Roentgenology. Defective equipment ranged from ultra-modern high voltage units to antiquated glass bowl devices with exposed high voltage lines.

It was found that the five-foot length recommended for switch cords is difficult to evaluate. In some instances, cord lengths somewhat less than five feet would have appeared to be satisfactory. Frequently however, cord lengths greater than five feet would be desirable. Most dental operatories are small and rather cramped. As a result, it is usually impossible to make full use of the cord length because of the location of the X-ray unit and the amount of other specialized equipment located in the room. Much can be said in favor of the new coil-type cords which will generally extend considerably more than five feet.

It is interesting to note that of the 140 X-ray units checked during this survey, only three were high voltage (90 kvp) units. One of these units was being operated at 65 kvp.

The extent X-ray examinations were used by the study group is indicated in figure 1. Several dentists who had requested a radiation survey of their offices reported that they did not normally take X-rays even though they owned functional equipment. At the other extreme, one dentist reported that he averaged about 400 exposures per week. The largest percentage of offices visited expose between 25 and 50 films per week.

Only 43 percent of the dentists were using "fast" film at the time of the inspection. A number of others stated that they had tried the fast film, but they were not satisfied with the quality of the radiograph. Some of those currently employing fast film were erroneously approximating the same exposures as used with regular speed film, and were reducing the developing time accordingly.

In monitoring the positions occupied by X-ray personnel during typical examinations, it was noted that most personnel realize the importance of keeping out of the primary beam. However, they were not cognizant of the hazard resulting from radiation scattered by the patient. The operator would frequently stand immediately behind the X-ray tube head which was approximately two or three feet from the patient. As a result, they were exposed to much higher levels of radiation than was necessary. It was ascertained, in most cases, that the best position for the operator during all types of X-ray examinations was directly behind the dental chair, as far as from the patient as the cord would allow. Although this position might be obvious for bitewing X-rays, it was found to be equally preferred for exposures with the beam pointed toward the rear. Evidently, the increased distance which this position affords more than compensates for any increased scatter in that direction.

Even though this study indicated that the operator position described above was preferred in a large number of cases, it would not necessarily hold true for all operatories. Radiation scattering is a very complex phenomenon which involves the design of the room and the actual arrangement of equipment. In reality, the only way to accurately evaluate an installation

is by measuring radiation levels at various positions with an appropriate radiation detection instrument.

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ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission submits to the Public Health Service quarterly reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 17 AEC installations have appeared in *Radiological Health Data,* Volume I, Numbers 8 and 9; and Volume II, Numbers 1 through 9. Summaries follow for Shippingport Atomic Power Station and Bettis Atomic Power Laboratory, third and fourth quarters of 1960.

The measured concentrations of radioactive substances in air and water may be compared with the Maximum Permissible Concentration (MPC) of that substance as recommended by the National Committee on Radiation Protection and Measurements (NCRP&M). For the general population, the applicable MPC's are one-tenth of the occupational values for continuous exposure as given in National Bureau of Standards "Handbook Number 69."

For the purpose of clarity and perspective, a few of the applicable environmental MPC values are listed in table 1 below. Such values are intended as guides only. For further clarification, "Handbook 69" should be consulted.

When various radioactive substances are considered separately the following relationship should be satisfied:

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} + \cdots\cdots \leqslant 1$$

in which C_A is the actual concentration of substance "1" and MPC_1 is its appropriate MPC, etc.

TABLE 1.

Radioactive substance	Environmental MPC's	
	Water ($\mu\mu c$/liter)	Air ($\mu\mu c/m^3$)
Gross activity of unidentified nuclides	10	0.04
Gross activity in water if Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{226}, Ra^{228}, Pa^{231}, and Th-natural are not present*	2,000	
Airborne particulate activity if there are no α-emitters and if Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, and Bk^{249} are not present*		100
Hydrogen-3 (Tritium)	3,000,000	200,000
Strontium-90	100	10
Xenon-133		300,000

* The term "not present" implies that the concentration of the radionuclide is small compared to its approximate MPC as listed in "Handbook 69."

Bettis Atomic Power Laboratory

Westinghouse Electric Corporation
Pittsburgh, Pennsylvania
Issued December 1960 and February 1961

Environmental levels of radioactivity at the Bettis Atomic Power Laboratory for 1959 and the first and second quarters of 1960 were reported in *Radiological Health Data*, Volume I, Number 8, and Volume II, Number 1. The following report presents the data for the third and fourth quarters of 1960 together with averages for the calendar year.

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission (AEC) by the Westinghouse Electric Corporation, was established in 1949. Since that time, BAPL has been engaged in research and development work related to naval atomic propulsion systems and the central station atomic power reactor at Shippingport.

Measurements are continually made to insure that controls on laboratory processes are adequate to prevent the release of radio active materials to the surrounding community. Measurements are also made in the area surrounding the laboratory in order to determine background levels of radioactivity. These measurements have shown that laboratory controls were effective in minimizing the release of radioactivity to the environment.

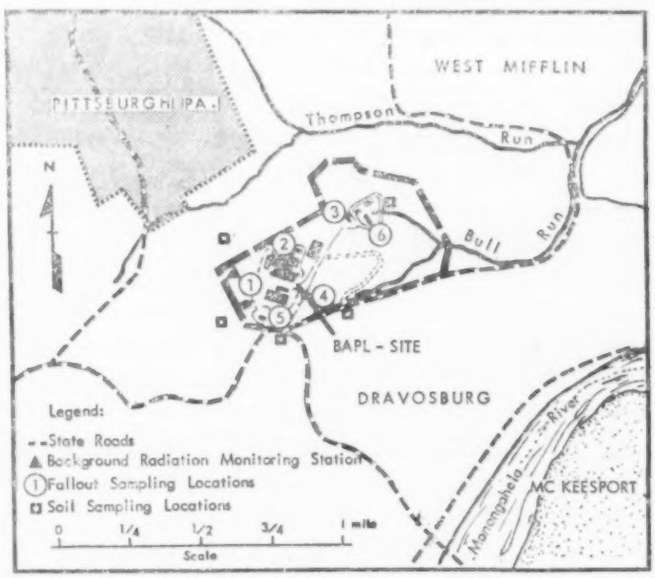

FIGURE 1.—BETTIS ATOMIC POWER LABORATORY SAMPLING STATIONS

Liquid Radioactive Waste Disposal

Laboratory liquid effluent is sampled continually and analyzed as a weekly composite. Its measured concentration may include fallout from rainfall and runoff that has entered the effluent line through the laboratory drainage system. Table 2 presents the concentrations of gross radioactivity and strontium-90 concentrations in the liquid effluent of the plant for third and fourth quarters, 1960. Calendar year averages are also included.

TABLE 2.—GROSS RADIOACTIVITY AND STRONTIUM-90 CONCENTRATIONS IN LIQUID WASTES, 1960

[Average concentrations in $\mu\mu c$/liter]

Period	Gross radioactivity[2]	Strontium-90
Second quarter		2.4
Third quarter	120	1.4
Fourth quarter	170	14.0
Calendar year	170	4.7

[1] The concentration of strontium-90 for the second quarter is included in this report because the analysis had not been completed in time to be included in its respective report. (See *Radiological Health Data* Volume II, Number 1.)
[2] The MPC used here for gross radioactivity is 2,000 $\mu\mu c$/liter (see table 1 in the introduction to these reports on AEC installations) because Sr^{90} is considered separately using the formula

$$\frac{C_A}{MPC}+\frac{C_B}{MPC}\leq 1$$

Where C_A is the concentration of gross radioactivity, and C_B is the concentration of strontium-90.

Beta-Gamma Background Radiation Levels

Beta-Gamma background radiation levels are continuously monitored and recorded at a monitoring station located inside the western boundary of laboratory property as shown in figure 1. The results of the data taken during the third and fourth quarters of 1960 are listed in table 3.

The background radiation levels in table 3 are within the range 0.01 to 0.04 mr/hr as measured in December 1960 by the Radiation Surveillance Network, Public Health Service, throughout the United States.

TABLE 3.—BETA-GAMMA BACKGROUND RADIATION LEVELS, 1960

[Average dose rate in millirads/hour]

Period	Beta-gamma background
Third quarter	0.017
Fourth quarter	0.018
Calendar year	0.017

Fallout

Radioactive fallout samples are collected at the six stations shown in figure 1. Measurements of fallout collected by these stations provide only approximate values that are useful in indicating trends or variations. Due to their locations, these stations measure not only day-to-day fallout from the atmosphere, but also may detect resuspended activity present in dust particles caused by the movement of vehicles and construction work in the immediate vicinity. Table 4 shows the data obtained from analyses of samples collected at these stations during the third and fourth quarters of 1960.

Based on prevailing wind directions, the sampling locations have been categorized as upwind or downwind, and the data are compared in an effort to determine what effect laboratory operations have in surrounding areas. The results reveal no significant differences that would indicate that the laboratory is contributing to fallout in the surrounding areas.

At the beginning of the fourth quarter, the method of collecting fallout samples was changed from gummed film, exposed for one week, to high-walled pots exposed for one month.

TABLE 5.—ALPHA AND BETA ACTIVITY IN SOIL, 1960

[Average concentrations in $\mu\mu c$/gram]

Period	Alpha	Beta
Fourth quarter	67	27
Calendar year	42	26

Soil Sampling

Soil samples from five locations shown in figure 1 are collected each year during the second and fourth quarters. Concentrations of radioactivity in the soil samples collected during the fourth quarter are shown in table 5.

TABLE 4.—AVERAGE BETA ACTIVITY IN FALLOUT, 1960

[Average concentration in mc/mi²/month]

Period	Station							
	Upwind			Downwind				
	No. 1	No. 5	Average	No. 2	No. 3	No. 4	No. 6	Average
Third quarter	2	2	2	3	2	3	2	3
Fourth quarter	2	2	2	3	3	2	2	3
Calendar year			4					4

Shippingport Atomic Power Station

Duquesne Light Company, Shippingport, Pennsylvania
Issued December 1, 1960 and March 1, 1961

Environmental levels of radioactivity at the Shippingport Atomic Power Station for 1959, and the first, and second quarters of 1960 were reported respectively in *Radiological Health Data*, Volume I, Numbers 4 and 9 and Volume II, Number 1, respectively. The following report presents a summary of the data for the third and fourth quarters of 1960, and averages for the calendar year of 1960.

The Shippingport Atomic Power Station, operated for the Atomic Energy Commission by the Duquesne Light Company, is the first large-scale nuclear-powered electric generating station. The plant resumed operations in May

1960 after a "shut-down" which lasted nearly six months, so that a portion of the reactor fuel could be replaced. Following this refueling, the plant operated at various power levels for nearly 4400 hours, and in 1960, it produced over 255 million kilowatt hours of electrical energy.

Liquid Radioactive Waste Monitoring

At Shippingport, most of the liquid wastes are discharged according to the limit for gross unidentified mixtures of radionuclides. This is done because the total quantity of radioactivity in the waste is of a low level and analyses for many specific radionuclides are laborious and expensive. However, the discharge of tritium is controlled separately, based on its own maximum allowable limit, since its formation in the reactor can be predicted with relative ease. These controls are applied to the actual plant discharges. No allowance is made for the dilution available in the environment except for that river water actually pumped through the plant for cooling the condensers.

TABLE 6.—SUMMARY OF GROSS RADIOACTIVITY RELEASED TO THE OHIO RIVER, 1960

Period	Total for month (μc)	Average per day (μc)	Average concentration effluent channel during release (μμc/liter)
Third quarter:			
July	9,596	309	2.3
August	7,275	234	1.9
September	11,881	395	2.9
Fourth quarter:			
October	20,305	655	3.0
November	8,198	273	2.4
December	10,486	338	3.4
1960 summary:			
First quarter		735	5.8
Second quarter		799	4.3
Third quarter		313	2.4
Fourth quarter		422	2.9
1960 average		567	3.8

TABLE 7.—SUMMARY OF TRITIUM RELEASED TO THE OHIO RIVER, 1960

Period	Total for month (curies)	Average per day (curies)	Average concentration in effluent channel during release (μμc/liter)
Third quarter:			
July	6,847	0.220	2,900
August	16,756	0.541	7,000
September	15,650	0.522	7,600
Fourth quarter:			
October	26,477	0.855	7,100
November	16,158	0.538	7,400
December	8,703	0.280	7,100
1960 summary:			
First quarter		0.00	0
Second quarter		0.03	1,100
Third quarter		0.43	3,300
Fourth quarter		0.58	7,200
1960 average		0.26	2,900

Tables 6 and 7 summarize the average gross radioactivity and tritium concentrations in the plant effluent channel during the third and fourth quarters, 1960. A review of the cal-

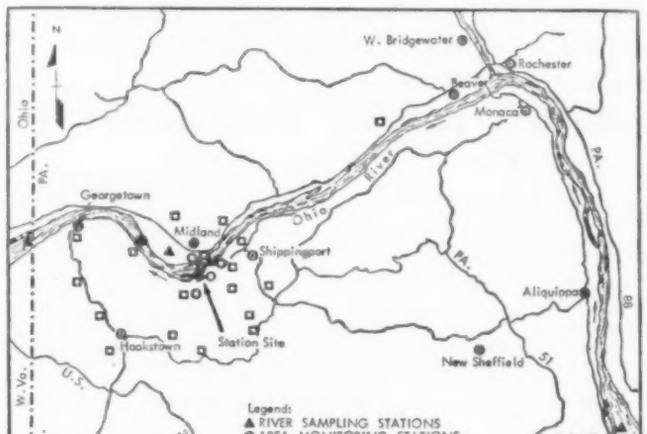

FIGURE 2.—SHIPPINGPORT POWER STATION, SAMPLING LOCATIONS

TABLE 8.—GROSS ALPHA AND BETA CONCENTRATIONS IN THE OHIO RIVER, 1960

[Average concentrations in μμc/liter]

Station	Third quarter							Fourth quarter						
	Number of samples	Suspended		Dissolved		Total		Number of samples	Suspended		Dissolved		Total	
		Alpha	Beta	Alpha	Beta	Alpha	Beta		Alpha	Beta	Alpha	Beta	Alpha	Beta
Upstream:														
Phillips	13	0.1	1.9	0.5	8.2	0.6	10.1	13	0.3	2.5	0.9	6.5	1.2	9.0
Shippingport	13	0.2	2.3	0.9	8.0	1.1	10.3	13	0.2	2.1	0.9	7.1	1.1	9.2
Downstream:														
Midland	13	0.1	1.6	0.6	8.1	0.7	9.6	13	0.2	2.2	0.4	7.0	0.6	9.2
E. Liverpool	13	0.6	4.5	1.2	7.1	1.8	11.6	13	0.1	2.7	0.5	7.2	0.6	9.2
Dam #7 (grab sample)	13	0.2	1.9	0.7	7.7	0.9	9.6	12	0.1	2.3	1.0	7.8	1.1	10.1

endar year of 1960 is also included in the tables.

River water samples are taken continuously at four locations upstream and downstream from Shippingport and they are analyzed weekly. Upstream sampling stations are located at the Phillips Power Station of the Duquesne Light Company (about 20 miles upstream) and at the condenser cooling water intake at Shippingport. The downstream continuous sampling stations are on the water intake lines of the water treatment plants at Midland, Pennsylvania, and East Liverpool, Ohio, approximately one and eight miles downstream, respectively. Weekly grab samples are also collected from the River at Dam Number 7. These locations are shown in figure 2.

TABLE 9.—SUMMARY OF AVERAGE GROSS BETA CONCENTRATION IN THE OHIO RIVER DURING 1960

[Average concentrations in $\mu\mu c$/liter]

Station	First quarter	Second quarter	Third quarter	Fourth quarter
Upstream	10	9	10	9
Downstream	11	9	10	10

Table 8 presents a summary of the gross alpha and beta concentrations of suspended and dissolved solids in the Ohio River during the third and fourth quarters, 1960. Table 9 reviews the gross beta concentrations for the calendar year 1960. About 60 percent of the beta activity shown in tables 8 and 9 has been shown to be potassium-40, which is part of the natural background.

Area Monitoring

During the third and fourth quarter of 1960, small quantities of gaseous radionuclides were released to the atmosphere from the waste disposal system.

In July, a total of 5,424 microcuries, composed primarily of xenon-133, were discharged at a controlled rate over a period of four and one-half hours. This gaseous waste had an average concentration of 79,000 $\mu\mu c/m^3$ of air at the stack exit during release. In December, a total of 23,555 microcuries also composed primarily of xenon-133, were discharged at a controlled rate over a period of 114 hours and 18 minutes. In this case, the average concentration was 13,000 $\mu\mu c/m^3$.

TABLE 10.—AIRBORNE PARTICULATE RADIOACTIVITY, 1960

[Average concentrations in $\mu\mu c/m^3$]

Period	Station				Average of all stations
	Upwind		Downwind		
	½ mi. SW of site	½ mi. NW of site	On site, SE of main bldg.	½ mi. NE of site	
Third quarter	2.5	1.7	1.7	2.3	2.0
Fourth quarter	2.0	1.7	1.4	2.4	1.9
Calendar year					1.5

An incinerator employed for burning contaminated combustible material is located in the waste disposal plant and it is generally used several times a month. The exhaust from the incinerator passes through a wet gas scrubber and a filter to remove any particulate radioactivity before entering the exhaust stack. It is monitored at the stack exit in order to record the levels of radioactivity leaving the plant. During the third and fourth quarters of 1960, the maximum radioactivity monitored at the stack exit during incinerator operations was 100 $\mu\mu c/m^3$. This level was noted and the average activity discharged that day was 3.4 $\mu\mu c/m^3$.

Four area monitoring stations continuously monitored and recorded background levels of beta-gamma radiation and airborne particulate radioactivity in the vicinity of Shippingport. (See tables 10 and 11). These stations are shown in figure 2. The data recorded by each station were checked and tabulated weekly. The data reported in table 10 are the results of measurements made only one hour after

TABLE 11.—GROSS BETA-GAMMA BACKGROUND RADIATION LEVELS, 1960

[Average values in millirad/hour]

Period	Station				Average of all stations
	Upwind		Downwind		
	½ mi. SW of site	½ mi. NW of site	On site, SE of main bldg.	½ mi. NE of site	
Third quarter	0.014	0.014	0.015	0.014	0.014
Fourth quarter	0.012	0.013	0.012	0.012	0.012
Calendar year					0.013

TABLE 12.—GROSS BETA ACTIVITY IN FALLOUT, 1960

[Average concentrations in mc/mi²/mo.]

Period	Station				Average of all stations
	Upwind		Downwind		
	½ mi. SW of site	½ mi. NW of site	On site, SE of main bldg.	½ mi. NE of site	
Third quarter	12.5	1.7	7.8	1.5	5.8
Fourth quarter	6.5	11.0	6.8	8.1	8.1
Calendar year	9.1	8.5	8.5	8.3	8.6

TABLE 13.—GROSS ALPHA AND BETA ACTIVITY IN SOIL SAMPLES

[Average concentrations in μμc/gm]

Period	Alpha	Beta
Third quarter, 1960	12	14
Fourth quarter, 1960	18	15
Calendar year, 1960	16	15
Preoperational, (1956–57)	15.4	15.8

sample collection, and therefore, natural radon activity would be included.

Fallout

Radioactive fallout is collected at the four area monitoring stations. Samples are picked up weekly for analyses of their gross beta radioactivity. The data for the third and fourth quarter and the calendar year averages are presented in table 12. The prevailing wind direction at Shippingport is generally from west to east. Data from the upwind stations are compared with that from the downwind stations in an effort to determine any effect which can be attributed to plant operations. These results do not indicate a contribution to fallout in the area from the Shippingport plant during 1960.

Soil Sampling

Soil samples were collected from twenty locations within a radius of approximately five miles of the Shippingport site during the third and fourth quarters of 1960. A comparison of this data with that taken during the preoperational survey shows no significant increase in soil concentrations.

Latitudinal Distribution of Strontium-90 [1]

Soil Conservation Service, U.S. Department of Agriculture; Health and Safety Laboratory, U.S. Atomic Energy Commission; and Weather Bureau, U.S. Department of Commerce

Sampling Sites and Methods

Sampling sites within the continental United States and other locations throughout the world have been selected to measure the total amount of strontium-90 fall-out in soil. The sites are level, or nearly so, have a complete vegetative cover, and are sufficiently permeable to absorb all the precipitation that falls on them. These sites receive no water from higher ground. The depth of sampling has increased in successive years because there has been some penetration of Sr^{90} downward into the soil with time. A 1959 study of penetration at a sandy site, where greater than average penetration was expected, indicated that 74 percent of the Sr^{90} was in the top 2 inches, 88 percent in the top 4 inches, 94 percent in the top 6 inches, and 97 percent in the top 8 inches. Trace amounts of Sr^{90} were reported to a depth of 16 inches. The sampling depth has been adequate in all cases to ensure that no significant amount of Sr^{90} was below the sample.

Every precaution has been taken to minimize the effect of redistribution that may have taken place since deposition. For example, sampling sites were not located in New Mexico, Nevada, and Wyoming because of the general redistribution of Sr^{90} due to the shifting of the surface soil by wind action. Some places lose material by wind action while others gain, but there is no simple way of determining the extent of this distribution. This may not be true of the complete area of these states, but it applies to the drier, more repre-

[1] Abstracted from "Strontium-90 on the Earth's Surface," U.S.A.E.C. TID 6567 February 1961.

sentative regions. To some extent, the blowing and drifting of the winter snows have a similar effect. However, errors due to redistribution are not thought to be serious in the sampling sites.

The samples were taken with two instruments, one is a "cookie cutter" that removes a 3.5-inches core to a depth of 2 inches. The other is an orchard auger which cuts a hole the same diameter as the cookie cutter, and removes the soil to the desired depth from its beginning depth of 2 inches. In some of the foreign samplers, Australia for example, the auger has a somewhat larger diameter. In all cases, the error in the measurement of the sampled area is not greater than about 1 or 2 percent.

The sample includes both living and dead vegetation. The final sample for analysis includes the proper fraction of any vegetation that segregates during sample preparation. Likewise, all rocks are crushed and included in the analyzed sample. The sample is usually a composite of 20 individual cores. The weight of sample ranges from 20 or 30 pounds for highly organic or peaty soils, to as much as 100 pounds for high-volume-weight soils taken to a depth of 10 inches.

Latitudinal Distributions of Strontium-90 Fallout

Figure 1 illustrates the latitudinal distribution of fall-out obtained from soil samples in 1956, 1958, and 1959. All the North-South profiles show the same general features: a pronounced peak in the 30 to 60°N band, a minimum in the equatorial region, and a weak secondary maximum in the Southern Hemispheric 30 to 60°S band. The reality of the secondary peak in the southern hemisphere is of some importance in the meteorological interpretation of the transport of stratospheric debris. Additional evidence for this

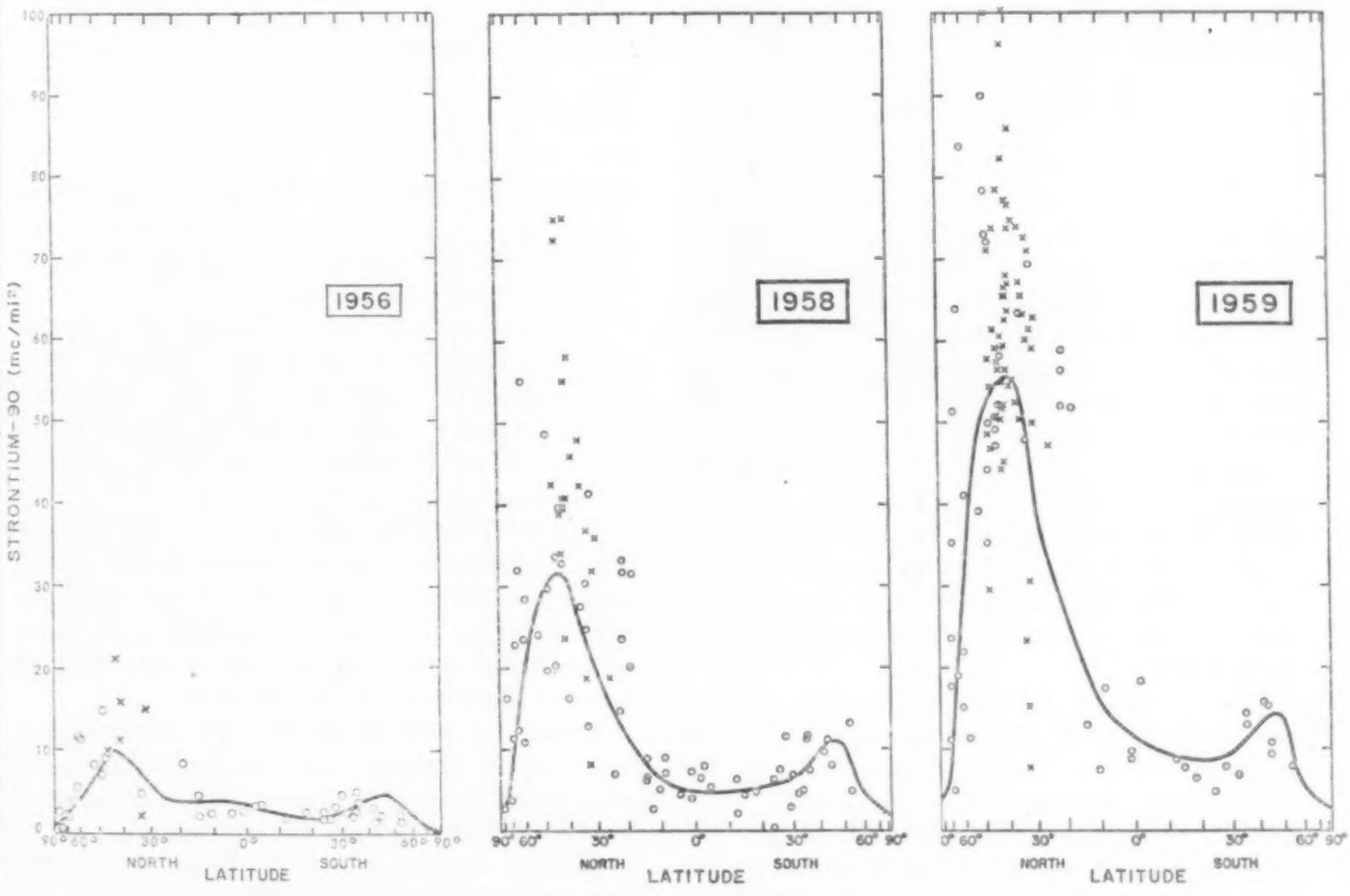

FIGURE 1.—SOIL STRONTIUM-90 AS A FUNCTION OF LATITUDE. CROSSES INDICATE SAMPLES COLLECTED IN THE CONTINENTAL UNITED STATES.

secondary maximum is given by the Naval Research Laboratory 80th meridian ground-level air-concentration measures (*1*), and to a limited extent by the Sr^{90} concentrations in rainfall (*2*).

Comparison With Production

A complete analysis of the inventory of Sr^{90} is beyond the scope of this report. However, other estimates (*3*) seem to be consistent with the soil data. The total production (*3*) of Sr^{90} to 1959 is given as 9.2 megacuries, assuming that 1-megaton equivalent fission energy corresponds to 0.1 magecuries of Sr^{90}. It has been estimated (*3*) that about 3.0 megacuries fell out in the first few hundred miles downward of the test sites as local fall-out. This fall-out is not considered to be part of the world-wide Sr^{90} deposition. The remaining 6.0 to 6.5 megacuries would have decayed to between 5.5 and 6.0 megacuries as of July 1959. The analysis of the soil data suggests that 4.1 megacuries have already been deposited. Knowledge of the atmospheric content is limited, but using the stratospheric baloon observations mainly in the period January to July 1959, it is estimated that 1.0 to 1.5 megacuries still remained in the stratosphere. The sum of the soil evaluation, 4.1 megacuries, and the uncertain stratospheric reservoir, 1.0 to 1.5 megacuries, is close to the estimate of world-wide Sr^{90}, 5.5 to 6.0 megacuries.

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Savannah Estuary Environmental Radiological Survey

Division of Radiological Health, Public Health Service

The Public Health Service, and the Bureau of Commercial Fisheries of the Department of Interior are conducting a long-range radiological study of the estuarial waters in the Savannah River system near Savannah, Georgia. Also participating in the study are the Coast Guard, U.S. Treasury Department, and the Corps of Engineers, U.S. Army.

The purpose of the study is to trace the routes of radionuclides in a marine environment from their source to possible human consumption via the "food web" and to study factors affecting the uptake or reconcentration of these nuclides by various forms of marine life.

The Savannah River estuary was selected for study since it represents one of the best estuaries in the United States suitable for radiological studies. The Savannah River estuary is ideally suited for such studies because a limited amount of radioactive wastes from the nuclear operations at the Savannah River plant are discharged into the river, which flows 120 miles to the estuary. The Savannah River Plant is operated for the Atomic Energy Commission by the E. I. du Pont de Nemours Company.

The survey has been planned to progress under a three-phase program. Phase I is to be conducted exclusively in the Savannah River estuary with initial sampling being conducted on a monthly, and later probably on a seasonal or quarterly basis.

Phase II will be conducted in the estuary and upstream on the Savannah River in the fresh waters which are out of the tidal intrusion area. Studies will include such items as sediment size as a function of activity and activity distributions in the river.

Phase III will be carried on for studying the over-all problem with particular emphasis on the inclusion of radionuclides into the food chain. Phases II and III are planned to be conducted concurrently with Phase I, and the project is scheduled for completion during the latter part of fiscal year 1963.

At present, Phase I is underway and it generally consists of monthly and seasonal collections of water and silt samples, shrimp and crabs, oysters, minnows and other types of fish life, together with marine plants. Samples collected to date have been sent to the Public Health Service Southeastern Radiological Health Laboratory at Montgomery, Alabama, where analyses for specific radioactive substances such as strontium-90 have been conducted. The Fish and Wildlife Service of the Bureau of Commercial Fisheries, Department of the Interior, is performing the specialized analyses of the marine organisms. The U.S. Coast Guard is providing ships and crews for carrying out the marine sampling program at the mouth of the Savannah River.

Samples for the initial phase of this radiological survey are being taken from the stations shown in figure 1. The graphs shown in figures 2 and 3 display the analytical results for the samples collected during the first four months of thes urvey. In addition to these results, figure 2 comparatively depicts the April 1952 data which were taken from the *Interim Report on the Savannah River Study, July 1951–June 1952*, issued by the Public Health Service, Department of Health, Education, and Welfare. This data was taken upstream of the tidal intrusion.

Control samples are being collected from the coastal waters of South Carolina at Edisto Beach and Beaufort. These control areas lie some 30 miles north of the Savannah River Estuary. The tidal currents along the South Carolina and Georgia coasts usually flow in a general southerly direction from the control areas towards the Savannah River Estuary. Therefore, it is felt that since the tidal currents are generally flowing away from the control areas, marine samples in the control areas would probably be unaffected by limited radioactive wastes discharged to the Savannah River.

The analytical results acquired to date from this surveillance program were reduced to average values. The average value for each sample analyzed was calculated by weighting with the size of the sample. However, those samples that were less than the minimum level of detectability were assigned a value of one-half of that level.

Due to the short four-month period of sampling and the small number of samples collected, the present data from this surveillance operation are considered to be insufficient for making definite conclusions. It is felt that continued sampling with the resulting increase in analytical results will yield definite conclusions concerning the base line background radiation levels of the Savannah River Estuary.

FIGURE 1.—SAVANNAH ESTUARY ENVIRONMENTAL RADIOLOGICAL SURVEY SAMPLING LOCATIONS

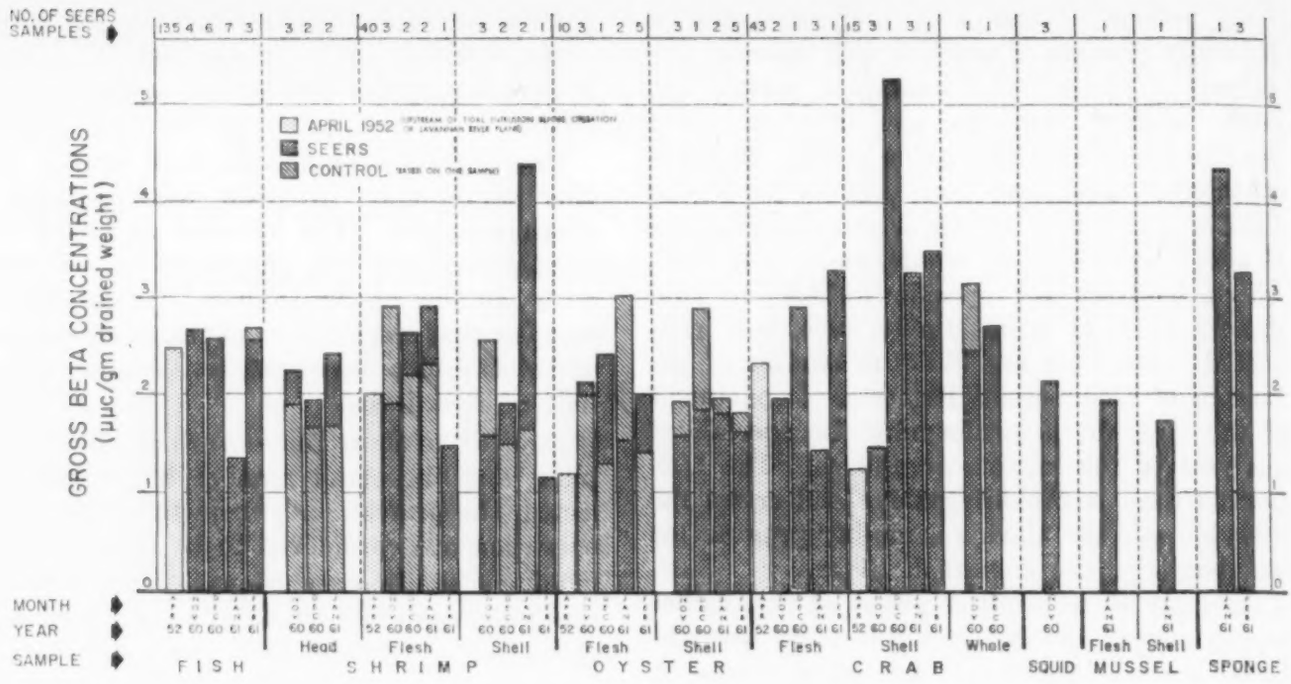


FIGURE 2.—GROSS BETA ACTIVITY, SAVANNAH ESTUARY BIOTA AND CONTROLS, BY SAMPLING PERIODS—APRIL 1952, NOVEMBER, DECEMBER 1960, JANUARY, FEBRUARY 1961

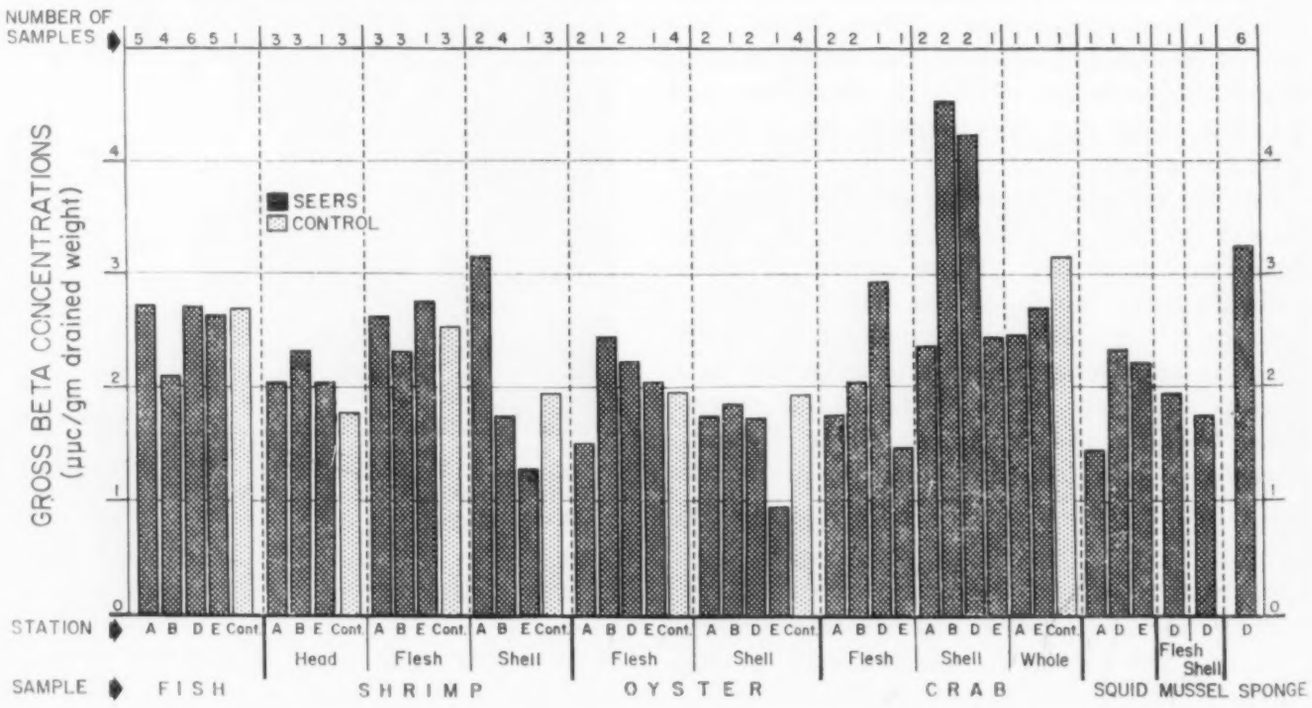


FIGURE 3.—GROSS BETA ACTIVITY, SAVANNAH ESTUARY BIOTA AND CONTROLS, BY SAMPLING STATIONS FOR NOVEMBER 1960–FEBRUARY 1961

Announced Russian Nuclear Detonations

On September 1, 1961 the Union of Soviet Socialist Republics resumed nuclear weapons testing in the atmosphere. They have utilized three test sites, the locations of which have the following geographic coordinates:

Semiplatinsk	52° N 78° E
Novaya-Semlya	75° N 55° E
East of Stalingrad	Not available

The following table presents the date, location and approximate size of the announced detonations through October 3, 1961.

Test Number	Location	Date	Size
1	Semiplatinsk	September 1, 1961	Intermediate kiloton range.
2	Semiplatinsk	September 4, 1961	Low kiloton range.
3	Semiplatinsk	September 5, 1961	Low-intermediate kiloton range.
4	East of Stalingrad	September 6, 1961	Low-intermediate kiloton range.
5	Novaya-Semlya	September 10, 1961	Several megaton range.
6	Novaya-Semlya	September 10, 1961	Low-intermediate kiloton range.
7	Novaya-Semlya	September 12, 1961	Several megaton range.
8	Semiplatinsk	September 13, 1961	Low-intermediate kiloton range.
9	Novaya-Semlya	September 13, 1961	Low-intermediate kiloton range.
10	Novaya-Semlya	September 14, 1961	Several megaton range.
11	Novaya-Semlya	September 16, 1961	Order of a megaton.
12	Semiplatinsk	September 17, 1961	Intermediate kiloton range.
13	Novaya-Semlya	September 18, 1961	Order of a megaton.
14	Novaya-Semlya	September 20, 1961	Order of a megaton.
15	Novaya-Semlya	September 22, 1961	Order of a megaton.
16	Novaya-Semlya	October 2, 1961	Order of a megaton.

Radiation Surveillance Measurements

There are several measurements that may be used to measure radiation levels in our environment. Each type of measurement provides a different kind of information and the type will be dependent on the degree of sophistication desired. In some cases, there may be a timelag for an isotope to appear in a medium. For instance, while there may be a certain percentage of iodine-131 in the surface air, it must be ingested by cows directly or enter plants through the root system for later ingestion before it can appear in the milk. Because of the conditions of some detonations, isotopes such as strontium-90 may not be deposited on the earth's surface for several months.

Gross Beta Determinations

Gross beta measurements may be determined on air, water, soil, or any desired media. As the name implies, this determination measures only the beta radioactivity without regard to the elements or isotopes emitting the radiation. Therefore, it is very difficult to interpret from beta measurements specific internal doses to the individual inhaling or ingesting the material.

Gross beta measurements are valuable, however, to determine the arrival of fallout and the concentration in the air mass. The filters may be used to determine the age of the fallout particles by measuring the rate of decay, and also for gamma spectroscopy to determine qualitatively the specific gamma emitting isotopes present on the filter.

To make measurements of the gross beta radiation in air, large volumes must be drawn through a filter to trap the particulates from the air. After a period of time which allows for the natural radioactivity to decay, the filter is counted in the laboratory to determine the amount of fission product activity. A field determination using a geiger counter may also be used to provide a rough quantitative answer. The result is usually expressed as micromicrocurie per cubic meter of air ($\mu\mu c/m^3$). The fact that there is beta activity in the air does

not necessarily indicate that fallout particles have been deposited on the ground. The particles are airborne and hence the concentration and the length of time the concentration exists at any one place is highly dependent on meteorological conditions.

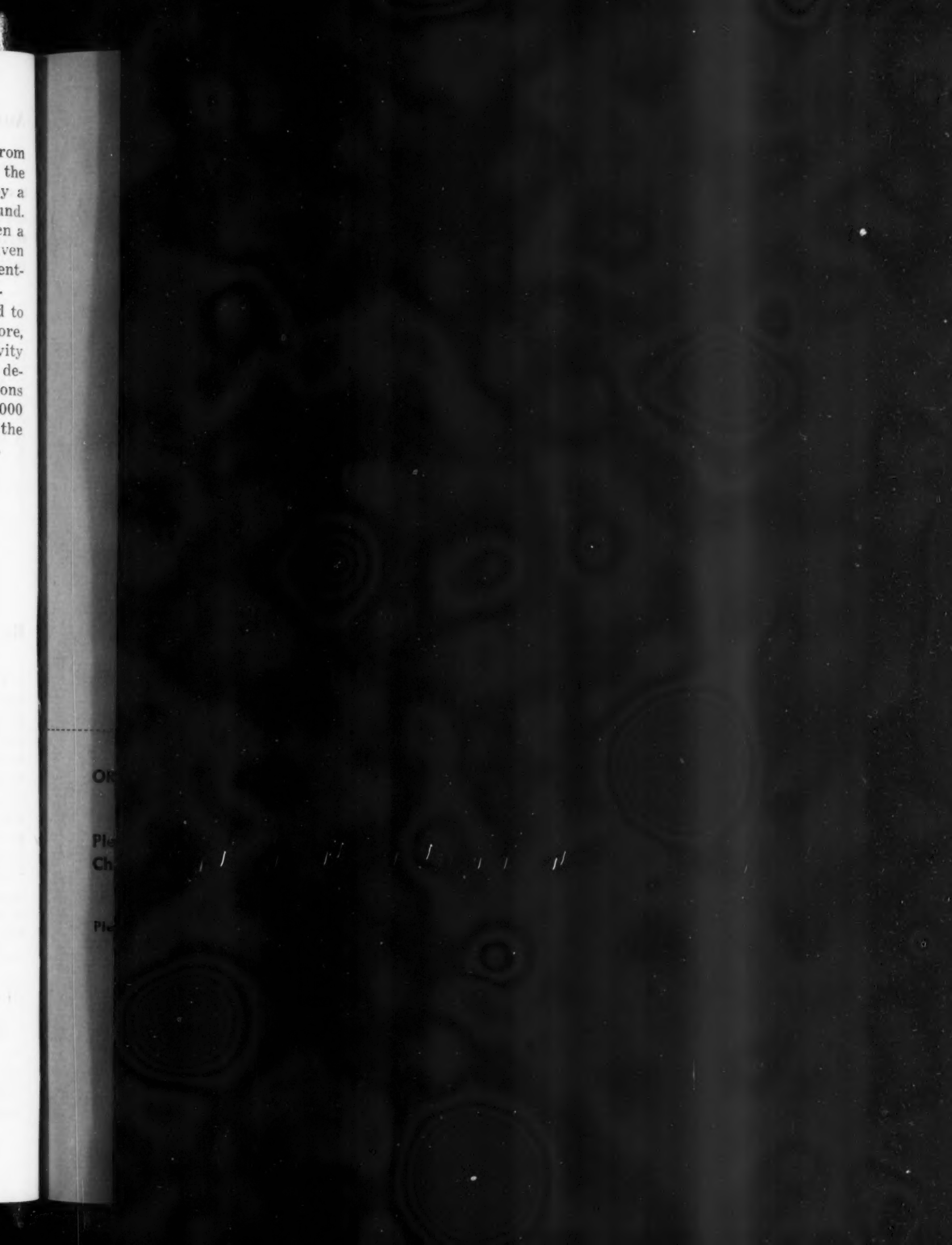
Isotopic Analyses

It is necessary to conduct isotopic analyses to determine the quantity of each isotope present in a sample to aid in the evaluation of the radiation dose to persons. The sample may be an air filter, soil, water, food, or milk. Gamma spectroscopy is used to determine the gamma emitting isotopes. Radiochemistry is usually necessary to identify isotopes, such as strontium-90, that are pure beta emittors.

External Gamma Measurements

External gamma radiation emanates from fallout particles that are deposited on the earth's surface. It is usually measured by a geiger counter held three feet above the ground. It is a measure of whole body exposure when a person remains at the same location for a given time and is generally expressed as milliroentgens per hour, or roentgen per hour (r/hr).

This type of measurement is not intended to assess levels of radioactivity in air, therefore, cannot be used to estimate such radioactivity concentrations. It is useful in measuring deposited radioactivity from fallout in situations which have shown air levels in excess of 100,000 $\mu\mu c/m^3$ or where precipitation has hastened the ground deposition of airborne fallout debris.



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